FORM PTO-1390 (REV 11-2000) U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE **TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371**		**ATTORNEY'S DOCKET NUMBER:** CITR1140 **U.S. APPLICATION NO** (If known, see 37 CFR 1 5) 09/807338
INTERNATIONAL APPLICATION NO. PCT/AU99/00873	**INTERNATIONAL FILING DATE** 12 October 1999	**PRIORITY DATE CLAIMED** 12 October 1998

TITLE OF INVENTION
MANAGEMENT OF PATH SELECTION IN A COMMUNICATIONS NETWORK

APPLICANT(S) FOR DO/EO/US
Ian Alexander Rose

OIPE
APR 11 2001
PATENT & TRADEMARK OFFICE

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 USC 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing 35 USC 371.
3. ☒ This is an express request to begin national examination procedures (35 USC 371(f)). The submission must include items (5), (6), (9), and (21) indicated below.
4. ☐ The US has been elected by the expiration of 19 months from the priority date (Article 31).
5. ☒ A copy of the International Application as filed (35 U.S.C. 371(c)(2))
   - a. ☒ is attached hereto (required only if not communicated by the International Bureau).
   - b. ☐ has been communicated by the International Bureau.
   - c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US)
6. ☐ An English language translation of the International Application as filed (35 USC 371(c)(2))
   - a. ☐ is attached hereto
   - b. ☐ has been previously submitted under 35 USC 154(d)(4)
7. ☐ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))
   - a. ☐ are attached hereto (required only if not communicated by the International Bureau).
   - b. ☐ have been communicated by the International Bureau.
   - c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   - d. ☐ have not been made and will not be made.
8. ☐ An English language translation of the amendments to the claims under PCT Article 19 (35 USC 371(c)(3)).
9. ☒ An oath or declaration of the inventor(s) (35 USC 371(c)(4)).
10. ☐ An English language translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 USC 371(c)(5)).

Items 11. to 16. below concern other document(s) or information included:

11. ☒ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
12. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. ☒ A FIRST preliminary amendment.
14. ☐ A SECOND or SUBSEQUENT preliminary amendment.
15. ☐ A substitute specification.
16. ☐ A change of power of attorney and/or address letter.
17. ☐ A computer-readable form of sequence listing in accordance with PCT Rule 13 and 35 USC 1821-1825
18. ☐ A second copy of the published International Application under 35 USC 154(d)(4).
19. ☐ A second copy of the English language translation of the International Application under 35 USC 154(d)(4).
20. ☒ Other items or information: Express Mail Certification; Copies of Receipt of Demand and Notification Concerning Submission Or Transmittal of Priority Document

JC02 Rec'd PCT/PTO 11 APR 2001

U.S. APPLICATION NO. (If known, see 37 CFR 1.5) 09/807338	INTERNATIONAL APPLICATION NO. PCT/AU99/00873		ATTORNEY'S DOCKET NO. CITR1140	
21. __ The following fees are submitted:			CALCULATIONS	PTO USE ONLY
BASIC NATIONAL FEE (37 CFR 1.492(A)(1)-(5)): Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2) paid to USPTO and International Search Report not prepared by the EPO or JPO..		$1,000.00	$1,000.00	
International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by EPO or JPO		$ 860.00		
International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO		$ 710.00		
International preliminary examination fee (37 CFR 1.482) paid to USPTO but all claims did not satisfy provisions of PCT Article 33(1)-(4).		$ 690.00		
International preliminary examination fee (37 CFR 1.482) paid to USPTO and all claims satisfied provisions of PCT Article 33(1)-(4).		$ 100.00		
ENTER APPROPRIATE BASIC FEE AMOUNT =			$1,000.00	
Surcharge of $130.00 for furnishing the oath or declaration later than_ 20_ 30 months from the earliest claimed priority date (37 CFR 1.492(e)).			$	

CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
Total Claims	30 - 20 =	10	x $ 18.00	$ 180.00	
Independent Claims	4 - 3 =	1	x $ 80.00	$ 80.00	
Multiple dependent claim(s) (if applicable)			+ $270.00	$ 270.00	
TOTAL OF ABOVE CALCULATIONS =				$ 1,530.00	
☒ Applicant claims small entity status. See 37 CFR 1.27. The fees indicated above are reduced by 1/2.				$ 765.00	
SUBTOTAL =				$ 765.00	
Processing fee of $130. for furnishing the English translation later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492(f)). +				$	
TOTAL NATIONAL FEE =				$ 765.00	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). $40.00 per property +				$	
TOTAL FEES ENCLOSED =				$ 765.00	
				Amount to be refunded:	**$**
				charged:	**$ 765.00**

a. ☒ A check in the amount of $ 765.00 to cover the above fees is enclosed. (Check No. 474058)
b. ☐ Please charge my Deposit Account No. 07-1895 in the amount of $ ______ to cover the above fees. A duplicate copy of this sheet is enclosed.
c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 07-1895 . A duplicate copy of this sheet is enclosed.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

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OIPE JC134 APR 11 2001 PATENT & TRADEMARK OFFICE

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I HEREBY CERTIFY THAT THIS PAPER OR FEE IS BEING DEPOSITED WITH THE UNITED STATES POSTAL SERVICE "EXPRESS MAIL POST OFFICE TO ADDRESSEE" SERVICE UNDER 37 CFR 1.10 ON THE DATE INDICATED ABOVE AND IS ADDRESSED TO THE ASSISTANT COMMISSIONER FOR PATENTS, WASHINGTON, D.C. 20231.

ANTOINETTE LITTLEFIELD

NAME

SIGNATURE

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of:

ROSE

Serial No.: Unknown

Filed: Herewith

Group No.: Unknown

Examiner: Unknown

Docket No. CITR1140

For: MANAGEMENT OF PATH SELECTION IN A COMMUNICATIONS NETWORK

BOX PATENT APPLICATION
Assistant Commissioner for Patents
Washington, D.C. 20231

Sir:

PRELIMINARY AMENDMENT

In advance of the first examination in this case, Applicants request amendment of the subject application, as follows:

IN THE CLAIMS

Please amend the claims as follows:

1. (Unchanged) A connection manager for selecting paths, from a plurality of paths available from service providers in a communications network, to route broadband traffic in the network, wherein the connection manager includes:

(a) a connection model indicating functional features supported by each path in the network and locations of terminations for respective paths;

(b) a cost model associated with the connection model that exposes to clients the cost of using the functional features for each path; and

(c) processing means, operated in response to a client requirement for a connection with desired features between two locations in the network, to –

(i) identify, from the connection model in light of the desired features, suitable candidate paths for routing communications traffic between the two locations and

(ii) determine, from the candidate paths and on the basis of cost exposed by the cost model, an optimal selection of paths connecting said locations.

2. (Unchanged) The connection manager as claimed in claim 1 wherein the functional features indicated by the connection model include one or more of the following:

(i) communications protocol;

(ii) transmission rate;

(iii) availability of the path; and

(iv) average error rate.

3. (Amended) The connection manager as claimed in claim 1 wherein the cost exposed by the cost model reflects the resources required to implement a path having a particular set of features.

4. (Amended) The connection manager as claimed in claim 1 wherein the path cost is determined in accordance with one or more of:

(i) number of network elements involved in the path;

(ii) reduction in network capacity experienced in implementing the path; and

(iii) funds required to implement the path.

5. (Amended) The connection manager as claimed in claim 1 wherein the cost model represents path costs as a data structure which is interpreted by the processing means.

6. (Unchanged) The connection manager as claimed in claim 5 wherein the data structure compromises a graph of cost nodes and each node specifies the cost of particular features or sets of features for respective paths.

7. (Unchanged) The connection manager as claimed in claim 6 wherein the cost nodes in the graph may be either internal for representing links between internal terminations in the connection model or external for the terminations at said predetermined locations.

8. (Amended) The connection manager as claimed in claim 1 wherein the cost model represents path cost as code which is executed by the processing means.

9. (Unchanged) The connection manager as claimed in claim 8 wherein the processing means for executing the code is an implementation of a Turing machine.

10. (Amended) The connection manager as claimed in claim 1 wherein the cost model further exposes the delay in implementing functional features supported by the path.

11. (Unchanged) The connection manager as claimed in claim 10 wherein the client requirement for a connection includes a desired minimum delay which is utilized as a further basis for determining the optimal selection of paths.

12. (Amended) The connection manager as claimed in claim 1 wherein individual terminations at the same location that have common attributes are represented as termination groups.

13. (Amended) A connection manager for selecting paths from a plurality of paths available from service providers in a communications network to route broadband traffic in the network, wherein the connection manager includes:

(a) a cost model provided by the service provider that exposes to clients the cost of using each path; and

(b) processing means, operated in response to a client requirement for a connection involving a plurality of terminations in the network, to -

(i) identify candidate paths for routing communications traffic amongst said plurality of terminations and

(ii) determine, from the candidate paths and on the basis of cost exposed by the cost model, a least cost selection of paths connecting said terminations.

14. (Unchanged) The connection manager as claimed in claim 13 wherein the cost model also exposes delay in the service provider making a path available.

15. (Amended) The connection manager as claimed in claim 13 wherein available paths include paths pre-existing in the network.

16. (Amended) The connection manager as claimed in claim 13 wherein available paths include paths that can be created by the service provider.

17. (Amended) The connection manager as claimed in claim 13 wherein the cost model exposes usage cost depending on the functional features required of each path.

18. (Amended) The connection manager as claimed in claim 13 wherein the cost exposed by the cost model reflects the resources required to implement a path having a particular set of features.

19. (Amended) The connection manager as claimed in claim 13 wherein the path cost is determined in accordance with one or more of:

(i) number of network elements involved in the path;

(ii) reduction in network capacity experienced in implementing the path; and

(iii) funds required to implement the path.

20. (Amended) The connection manager as claimed in claim 13 wherein the cost model represents path cost as a data structure which is interpreted by the processing means.

21. (Amended) The connection manager as claimed in claim 13 wherein the cost model represents path cost as code which is executed by the processing means.

22. (Amended) The connection manager as claimed in claim 13 wherein a cost model is transferred from each service provider.

23. (Amended) The connection manager as claimed in claim 13 wherein the client is a superior connection manager and a superior cost model is constructed from an aggregate of cost models transferred by subordinate connection managers.

24. (Unchanged) A selection method for selecting paths, from a plurality of paths available from service providers in a communications network, to route broadband traffic in the network, including the steps of:

(a) creating a connection model that indicates functional features supported by each path in the network and locations of terminations for respective paths;

(b) creating a cost model associated with the connection model that exposes to clients the cost of using the functional features for each path; and

(c) processing a client requirement for a connection with desired features between two locations in the network by –

(i) Identifying, from the connection model in light of the desired features, suitable candidate paths for routing communications traffic between the two locations and

(ii) determining, from the candidate paths and on the basis of the cost exposed by the service provider, an optimal selection of paths connecting said locations.

25. (Unchanged) The selection method of claim 24 wherein the setup of creating the connection model reflects attributes of network elements deployed by each service provider.

26. (Unchanged) A method of managing selection of paths from a plurality of paths available from service providers in a communications network to route broadband traffic in the network, said method including the steps of:

(a) creating a cost model whereby a service provider exposes to clients the cost of using each path;

(b) processing a client requirement for a connection involving a plurality of terminations by

(i) identifying candidate paths for routing communications traffic amongst said plurality of terminations and

(ii) determining, from the candidate paths and on the basis of cost exposed by the cost model, a least cost selection of paths connecting said terminations.

27. (Unchanged) The method of managing selection as claimed in claim 26 wherein the cost model is transferred from the service provider.

28. (Unchanged) The method of managing route selection as claimed in either claim 26 or claim 27, wherein the client is a superior connection manager and a superior cost model is constructed from an aggregate of cost models transferred from subordinate connection managers.

REMARKS

Claims 3-5, 8, 10, 12, 13 and 15-23 have been amended. Claims 1-28 remain in the application.

This Preliminary Amendment is submitted in advance of the first examination of the subject application. No new matter has been entered.

Respectfully submitted,

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VERSION WITH MARKS SHOWING CHANGES

1. (Unchanged) A connection manager for selecting paths, from a plurality of paths available from service providers in a communications network, to route broadband traffic in the network, wherein the connection manager includes:

(a) a connection model indicating functional features supported by each path in the network and locations of terminations for respective paths;

(b) a cost model associated with the connection model that exposes to clients the cost of using the functional features for each path; and

(c) processing means, operated in response to a client requirement for a connection with desired features between two locations in the network, to –

(i) identify, from the connection model in light of the desired features, suitable candidate paths for routing communications traffic between the two locations and

(ii) determine, from the candidate paths and on the basis of cost exposed by the cost model, an optimal selection of paths connecting said locations.

2. (Unchanged) The connection manager as claimed in claim 1 wherein the functional features indicated by the connection model include one or more of the following:

(i) communications protocol;

(ii) transmission rate;

(iii) availability of the path; and

(iv) average error rate.

3. (Amended) The connection manager as claimed in [either] claim 1 [or claim 2] wherein the cost exposed by the cost model reflects the resources required to implement a path having a particular set of features.

4. (Amended) The connection manager as claimed in [any one of] claim[s] 1 [to 3] wherein the path cost is determined in accordance with one or more of:

(i) number of network elements involved in the path;

(ii) reduction in network capacity experienced in implementing the path; and

(iii) funds required to implement the path.

VERSION WITH MARKS SHOWING CHANGES

5. (Amended) The connection manager as claimed in [any one of] claim[s] 1 [to 4] wherein the cost model represents path costs as a data structure which is interpreted by the processing means.

6. (Unchanged) The connection manager as claimed in claim 5 wherein the data structure compromises a graph of cost nodes and each node specifies the cost of particular features or sets of features for respective paths.

7. (Unchanged) The connection manager as claimed in claim 6 wherein the cost nodes in the graph may be either internal for representing links between internal terminations in the connection model or external for the terminations at said predetermined locations.

8. (Amended) The connection manager as claimed in [any one of] claim[s] 1 [to 4] wherein the cost model represents path cost as code which is executed by the processing means.

9. (Unchanged) The connection manager as claimed in claim 8 wherein the processing means for executing the code is an implementation of a Turing machine.

10. (Amended) The connection manager as claimed in [any one of] claim[s] 1 [to 9] wherein the cost model further exposes the delay in implementing functional features supported by the path.

11. (Unchanged) The connection manager as claimed in claim 10 wherein the client requirement for a connection includes a desired minimum delay which is utilized as a further basis for determining the optimal selection of paths.

12. (Amended) The connection manager as claimed in [any one of the preceding] claim[s] <u>1</u> wherein individual terminations at the same location that have common attributes are represented as termination groups.

VERSION WITH MARKS SHOWING CHANGES

13. (Amended) [The] A connection manager for selecting paths from a plurality of paths available from service providers in a communications network to route broadband traffic in the network, wherein the connection manager includes:

(a) a cost model provided by the service provider that exposes to clients the cost of using each path; and

(b) processing means, operated in response to a client requirement for a connection involving a plurality of terminations in the network, to -

(i) identify candidate paths for routing communications traffic amongst said plurality of terminations and

(ii) determine, from the candidate paths and on the basis of cost exposed by the cost model, a least cost selection of paths connecting said terminations.

14. (Unchanged) The connection manager as claimed in claim 13 wherein the cost model also exposes delay in the service provider making a path available.

15. (Amended) The connection manager as claimed in [either] claim 13 [or claim 14] wherein available paths include paths pre-existing in the network.

16. (Amended) The connection manager as claimed in [either] claim 13 [or 14] wherein available paths include paths that can be created by the service provider.

17. (Amended) The connection manager as claimed in [any one of] claim[s] 13 [to 16] wherein the cost model exposes usage cost depending on the functional features required of each path.

18. (Amended) The connection manager as claimed in [any one of] claim[s] 13 [to 16] wherein the cost exposed by the cost model reflects the resources required to implement a path having a particular set of features.

19. (Amended) The connection manager as claimed in [any one of] claim[s] 13 [to 18] wherein the path cost is determined in accordance with one or more of:

(i) number of network elements involved in the path;

(ii) reduction in network capacity experienced in implementing the path; and

(iii) funds required to implement the path.

20. (Amended) The connection manager as claimed in [any one of] claim[s] 13 [to 19] wherein the cost model represents path cost as a data structure which is interpreted by the processing means.

VERSION WITH MARKS SHOWING CHANGES

21. (Amended) The connection manager as claimed in [any one of] claim[s] 13 [to 20] wherein the cost model represents path cost as code which is executed by the processing means.

22. (Amended) The connection manager as claimed in [any one of] claim[s] 13 [to 21] wherein a cost model is transferred from each service provider.

23. (Amended) The connection manager as claimed in [any one of] claim[s] 13 [to 22] wherein the client is a superior connection manager and a superior cost model is constructed from an aggregate of cost models transferred by subordinate connection managers.

24. (Unchanged) A selection method for selecting paths, from a plurality of paths available from service providers in a communications network, to route broadband traffic in the network, including the steps of:

(a) creating a connection model that indicates functional features supported by each path in the network and locations of terminations for respective paths;

(b) creating a cost model associated with the connection model that exposes to clients the cost of using the functional features for each path; and

(c) processing a client requirement for a connection with desired features between two locations in the network by –

(i) Identifying, from the connection model in light of the desired features, suitable candidate paths for routing communications traffic between the two locations and

(ii) determining, from the candidate paths and on the basis of the cost exposed by the service provider, an optimal selection of paths connecting said locations.

25. (Unchanged) The selection method of claim 24 wherein the setup of creating the connection model reflects attributes of network elements deployed by each service provider.

26. (Unchanged) A method of managing selection of paths from a plurality of paths available from service providers in a communications network to route broadband traffic in the network, said method including the steps of:

(a) creating a cost model whereby a service provider exposes to clients the cost of using each path;

(b) processing a client requirement for a connection involving a plurality of terminations by

(i) identifying candidate paths for routing communications traffic amongst said plurality of terminations and

(ii) determining, from the candidate paths and on the basis of cost exposed by the cost model, a least cost selection of paths connecting said terminations.

27. (Unchanged) The method of managing selection as claimed in claim 26 wherein the cost model is transferred from the service provider.

28. (Unchanged) The method of managing route selection as claimed in either claim 26 or claim 27, wherein the client is a superior connection manager and a superior cost model is constructed from an aggregate of cost models transferred from subordinate connection managers.

~~MANAGEMENT OF PATH SELECTION IN A COMMUNICATIONS NETWORK~~

FIELD OF THE INVENTION

This invention relates to the management of connections in a large scale heterogeneous communications network, such as those operated by telecommunications utility companies and utilised by different carriers and service providers. In particular the invention relates to a method and apparatus for selecting paths in a broadband network that may be provided to customers requiring a communications service.

BACKGROUND TO THE INVENTION

The term "communications network" as used in the specification, is meant to encompass networks suitable for voice telephony and for data communications. Such communications networks may be suitable for switching and transporting voice, data, sound and/or image traffic, otherwise referred to as broadband or "multimedia" communications.

Existing communications networks are characterised by a number of transmission mediums using a variety of network technologies, protocols, software applications and equipment sourced from different vendors. Whilst much of the equipment includes management functions, such as monitoring, test and alarm features; the centralising, handling and controlling of network management functions in a complex multi-vendor environment is a significant problem.

A further problem in a heterogeneous network - which might include customer access technologies (ADSL, HFC), core network technologies (ATM, frame relay) and transmission technologies (SONET/SDH, WDM) - is that the management of end-to-end connections is typically conducted according to a lowest common denominator philosophy. The services provided by the network are limited to those able to be supported by the least capable equipment in the network. This philosophy is very ineffective in utilising the full capability of the diverse communications paths available in a network to meet particular service requirements of customers.

Glossary

AAD:	ATM access device
ADSL:	advanced digital subscriber line
ATM:	asynchronous transfer mode
CMIP:	common management information protocol
CORBA:	common object request broker architecture
EMS:	element management system
HFC:	hybrid fibre-optic co-axial
NMS:	network management system
NTU:	network terminal unit
OSS:	operational support system
VPC:	virtual path connection
SDH:	synchronous digital hierarchy
SNMP:	simple network management protocol
SONET:	synchronous optical network
TCP/IP:	transmission control protocol / Internet protocol
TL/1:	Bellcore interface protocol for network management
VCI:	virtual circuit identifier
VPI:	virtual path identifier
WDM:	wave division multiplexing

OBJECT OF THE INVENTION

It is an object of the present invention to provide a connection manager for selecting paths from a plurality of paths available in a communications network to route broadband traffic between predetermined locations in the network which ameliorates or overcomes at least some of the problems associated with the prior art.

It is another object of the invention to provide a path selection method for use in a communications network contributing to cost effective use of path features for routing broadband traffic between predetermined locations in the network.

Further objects will be evident from the following description.

DISCLOSURE OF THE INVENTION

In a form, the invention resides in a connection manager for selecting paths from a plurality of paths available from service providers in a communications network to route broadband traffic in the network, wherein the connection manager includes:

(a) a connection model indicating functional features supported by each path in the network and locations of terminations for respective paths;

(b) a cost model associated with the connection model that exposes to clients the cost of using the functional features for each path; and

(c) processing means, operated in response to a client requirement for a connection with desired features between two locations in the network, to -

  (i) identify, from the connection model in light of the desired features, candidate paths for routing communications traffic between the two locations and

  (ii) determine, from the candidate paths and on the basis of cost exposed by the cost model, an optimal selection of paths connecting said locations.

Preferably the functional features indicated by the connection model include one or more of the following:

(i) communications protocol;

(ii) transmission rate;

(iii) availability of the path; and/or

(iv) average error rate.

Preferably the cost exposed by the cost model reflects the resources required to implement a path having a particular set of features.

The path cost may be determined in accordance with the service provider's business rules or technical requirements, including one or more of:

(i) number of network elements involved in the path;

(ii) reduction in network capacity experienced in implementing the path; and/or

(iii) funds required to implement the path.

In one arrangement the cost model represents path cost as a data structure which is interpreted by the processing means.

Suitably the data structure comprises a graph of cost nodes wherein each node specifies the cost of particular features or sets of features for respective paths.

The cost nodes in the graph may be either internal for representing links between internal terminations in the connection model or external for the terminations at said predetermined locations.

In another arrangement the cost model represents path cost as code which is executed by the processing means.

Suitably the processing means for executing the code is an implementation of a Turing machine.

If required the cost model further exposes to clients the delay in implementing functional features supported by the path.

Where the cost model indicates implementation delay, the client requirement for a connection may include a desired minimum delay.

Suitably, individual terminations at the same location that have common attributes are represented as termination groups.

In another form the invention resides in a connection manager for selecting paths from a plurality of paths available from service providers in a communications network to route broadband traffic in the network, wherein the connection manager includes:

(a) a cost model provided by each service provider that exposes to clients the cost of using functional features supported by each path; and

(b) processing means, operated in response to a client requirement for a connection with desired features involving a plurality of terminations in the network, to -

  (i) identify, in light of the desired features, candidate paths for routing communications traffic amongst said plurality of terminations and

  (ii) determine, from the candidate paths and on the basis of cost exposed by the cost model, a least cost selection of paths connecting said terminations.

The cost model suitably also exposes to clients delay in the respective service provider making a path available.

The available paths may include paths pre-existing in the network and/or paths which can be created by the respective service provider.

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If required, the cost model suitably exposes usage cost depending on functional features required of each path by making cost offers to the client, which cost offers are valid for a predetermined time.

Most suitably the cost model is transferred to the connection manager from each service provider.

The service providers may include network managers for management of network elements.

The connection manager may be installed in an environment wherein its client is a superior connection manager and a superior cost model is constructed from an aggregate of cost models transferred by subordinate connection managers.

In a further form, the invention resides in a selection method for selecting paths from a plurality of paths available from service providers in a communications network, to route broadband traffic in the network, said method including the steps of:

(a) creating a connection model that indicates functional features supported by each path in the network and locations of terminations for respective paths;

(b) creating a cost model associated with the connection model that exposes to clients the cost of using the functional features for each path; and

(c) processing a client requirement for a connection with desired features between two locations in the network by -

  (i) identifying, from the connection model in light of the desired features, candidate paths for routing communications traffic between the two locations and

  (ii) determining, from the candidate paths and on the basis of the cost exposed by the cost model, an optimal selection of paths connecting said locations.

Suitably the step of creating the connection model reflects attributes of network elements deployed by the service provider.

In a yet further form the invention resides in a method of managing selection of a path from a plurality of paths available from service providers in a communications network to route broadband traffic in the network, said method including the steps of:

(a) providing a cost model whereby each service provider exposes to clients the cost of using functional features supported by each path in the network; and

(b) processing a client requirement for a connection with desired features involving a plurality of terminations by -

(i) identifying, in light of desired features, candidate paths for routing communications traffic amongst said plurality of terminations, and

(ii) determining, from the candidate paths and on the basis of cost exposed by the cost model, a least cost selection of paths connecting said terminations.

The method of managing selection may be undertaken in an environment wherein the client is a superior connection manager and a superior cost model is constructed from an aggregate of cost models transferred by subordinate connection managers.

BRIEF DETAILS OF THE DRAWINGS

To assist in understanding the invention preferred embodiments will now be described with reference to the following figures in which:

FIG. 1 is a diagram of a heterogeneous communications network including a hierarchy of connection managers;

FIG. 2A is a diagram illustrating the structure of a connection manager of a first embodiment;

FIG. 2B is a diagram illustrating interaction of a connection manager of a further embodiment with service providers;

FIG. 3 is a diagram of a world view from the perspective of the abstract connection model of the first embodiment;

FIG. 4 is an illustration of the physical architecture of an example network;

FIG. 5 is a top level view of a connection model for the network of FIG. 4;

FIG. 6A is a schematic diagram of an access device;

FIG. 6B is a cost graph for the access device of FIG. 6A;

FIG. 7A is a schematic diagram of a multiplexer;

FIG. 7B is a cost graph for the multiplexer of FIG. 7A;

FIG. 8A is a schematic diagram of an edge switch;

FIG. 8B is a cost graph of the edge switch of FIG. 8A;

FIG. 9 is a cost graph of a core switch supporting local switching;

FIG. 10 is an alternative cost graph of the core switch of FIG. 9;

FIG. 11 is shows a proposed (cost-free) link between two cost graphs;

FIG. 12 is shows a link between the cost graphs of FIG. 11;

FIG. 13A shows a proposed link between two further cost graphs;

FIG. 13B shows an aggregated cost graph of the two further cost graphs;

FIG. 14 shows a aggregated cost graph for the core domain of the network of FIG. 4;

FIG. 15 shows a cost graph used for modeling the network of FIG. 4;

FIG. 16 shows the cost graph of FIG. 15 re-shaped to illustrate a preferred path selection method;

FIG. 17 illustrates the principles of the path selection method; and

FIG. 18 illustrates the path selection method applied to the re-shaped cost graph of FIG. 16.

DETAILED DESCRIPTION OF THE DRAWINGS

The embodiment of the invention is described in the environment of a heterogeneous communications network 10 as illustrated in FIG. 1. The connection manager of the embodiment participates in the service activation and service assurance processes of large communications networks. The connection manager is suited to use in relation to broadband communications products which have significant complexity at the "Network Layer" (as defined by the ITU-T layered management model) - such as ATM, SDH, IP and bundled broadband products. The connection manager supports configuration and security activities at the Network Layer and can cooperate with other systems performing these functions for subsets of the communications network. The connection manager of the embodiment resides in a network management layer 30 between the service layer 20 and the network element layer 40.

The service layer 20 typically includes service order systems 21 which institute the creation of new connections and facilitates the query, modification and deletion of existing connections and pre-sales systems 23 which support pre-sales activities including inquiries regarding available connection characteristics,

connection cost and time frame. Examples of service layer systems include service order, customer network management (CNM) or wholesale gateway.

The network element layer 40 typically includes the hardware for providing network services such as switching or transmission, for example ADSL/HFC customer access technologies 41, ATM core network broadband technologies 42, and transport technologies 43 such as SONET/SDH or WDM. The network element hardware may be conceptually considered to reside in different "domains" and is typically also proprietary in nature. Accordingly, the network element hardware generally uses proprietary or compatible network element managers which act as proxies for many of the network elements.

Examples of network element managers are EMS systems 44 and 45 for the ADSL/HFC hardware, the NMS 46 for the ATM core hardware and the vendor specific NMS 47, 48 for the transport domain. Although the network element managers manage many network elements, they expose each network element as an individual entity. Thus in other embodiments, the connection manager may interface directly to the network elements.

The network management layer 30 of the embodiment illustrates the flexibility of the connection manager. A first connection manager 31 is interfaced to the EMS systems 44 and 45 for managing the customer access domain 40A. The functional flexibility of the connection manager arises from its ability to manage the functionally different requirements of the switch matrix EMS 44 and the AAD EMS 45. A second connection manager 32 manages the core domain 40C and a third connection manager 33 is interfaced to the vendor NMS systems 47 and 48 in the transport domain 40T. The transport domain illustrates the ability of the connection manager to handle disparate vendor equipment. The connection managers include interfaces which communicate using the CMIP, SNMP, TL/1 or proprietary protocols as required. These interfaces may be adapted to suit particular vendors' equipment, current or future.

A fourth superior connection manager 34 is interfaced with the three domain connection managers 31, 32 and 33 for the purpose of cross-domain connection management. The superior or cross-domain manager 34 level accepts end-to-end connection instructions for the entire network, it determines which paths through the underlying networks are available and issues connection instructions to the

domain connection managers as appropriate. The connection task is thus delegated to the appropriate domain connection managers.

Although shown as four separate managers, the network management layer 30 may be viewed as undertaking the overall connection management function for the network, with the cross-domain connection and domain connection being managed at different levels. Thus the network wide connection requirement is simplified step by step so that each level of connection management can be optimised to manage the portions of the network under its control. However, the separate connection managers illustrate the distributed nature of a network wide connection manager 35 which may be geographically distributed across a large number of sites and network operations centres.

Network Models

The connection manager provides flexible network modeling tools for representing a service provider or network owner's view of broadband connections. The key concepts for these representations are:

(i) "paths" which represent the network owner's view of a connection having the ability to transmit data over a communications network, such as ATM PVC;

(ii) "terminations" where the path is manifest outside of a network, such as an ATM VPI, VCI and cable, or a customer NTU; and

(iii) "features" which are the external selectable characteristics of the path visible at its terminations, such as quality of service, bit rate or path diversity.

Conceptually a path can negotiate many network elements and protocols, such as end-to-end SDH connections implemented using SDH switches and WDM transmission.

Connection Manager Structure

The structure of a generic connection manager 35 of one embodiment is described in relation to FIG. 2A, as it might be deployed in relation to a particular network. A connection model 36 is used to expose to clients the network and its services, which model may be implemented by the core software 37 for execution by a processor (not shown) or a series of distribute processors. Network adapters 38 are provided to interface with network elements, EMS or other NMS; whilst service adaptors 39 are provided to interface to existing service OSS.

The connection manager 35 supports several fundamental operations relating to the life cycle of a path. The service provider or network owner may instruct that a path be *reserved*, *created* or *changed*, which results in the automatic selection, allocation and configuration of appropriate network equipment to implement a connection with the specified features between specified terminations. A *remove* operation frees the allocated network equipment.

The connection manager allows the determination of which features are supported, in what combinations and at what localities in the network. Terminations and paths may be searched and listed, and the termination which best supports a given set of features in a locality suggested to a client by the connection manager.

The connection manager 35 of the embodiment preferably uses a CORBA IIOP architecture to interface to both the service layer and the network layer. The service layer interface and the network model can be adapted to present some standard data models, such as ETSI 600-653 or ATM Forum M4, or adapted to existing service layer interfaces. All connection manager objects can be annotated with the names and identifiers required by external systems, for example customer circuit identifiers.

The connection manager is a high-availability system supporting on-line changes to configuration with back-out, on-line database backup, replicated databases and redundant hardware. Depending on configuration, the connection manager will support 10,000 transactions per hour on one mid-range server machine (for example Hewlett Packard J-class). This typically corresponds to a network with 50 million installed paths with a typical operational latency is 0.3 seconds.

One connection manager installation can be distributed, as indicated above, over a number of server machines. A distributed installation on up to 10 machines would be typical, as transaction processing scales approximately linearly over this range. Such installation can suitably support HP UX or Solaris on SUN Solaris, Microsoft's NT on Intel or PA-RISC operating systems. Oracle™ database and Orbix™ ORB are also used in the preferred embodiment.

FIG. 3 shows a view of the world from the perspective of a connection model, considered in the abstract. A connection model is a framework for describing communications systems involving connections. In particular, the abstract connection model 50 of the embodiment is a distributed, object oriented

way of representing the state and operations required to manage the network layer 30 of a broadband communications network. The service layer 20 is effectively the driver for the connection model in that providing function to the service layer is the role of the connection model.

In order to address requests from the service layer the connection model delegates to either the network element layer 40 - in the form of either network elements 53 or network element managers 54 or other providers at the network management layer - for example workflow managers 51, network managers 52, other connection managers 55 or network service providers (NSP) 56. The choices involved in performing delegation include: (a) to which subordinates are functions delegated? (b) how are super-functions mapped to subordinates? (c) what is the sequencing of subordinate operations? and (d) what actions occur when a subordinate operation fails?

The abstract connection model 50 is suitably instantiated for operational use, with the instantiation depending on:

(i) the particular networking technology employed by the network owner;

(ii) the network owner's engineering rules; and

(iii) the network owner's service level requirements.

It is the model's instantiation 36 that gives meaning to the components of the model, such as path, feature and termination. When a connection model is instantiated, each of the abstract concepts that it presents will have a precise meaning. Furthermore, a model instantiation will have objects instantiated against it which objects will conform to both the abstract connection model and the instantiated model.

The development of a connection manager application normally includes the following three stages:

- Network analysis and design – the focus of this stage is to define the architecture of the network to be managed and to analyse the characteristics of each component of the network.
- Connection manager installation – the focus of this stage is to use the mechanisms supported by the core software to specify how the network should be managed. The installation is the outcome of this stage.

- Run time – once a connection management system is installed, paths can be created through the network to provide communications services.

Basic Concepts

The basic concepts for connection management used by the connection model are the path-termination-feature concepts, as introduced briefly above. A *feature* is a characteristic of a path that is required by a client or customer, and is manifest to the client of the path. Typical features include data transfer protocol, bandwidth, reliability and error rate; for example: ATM protocol, 64kb/s data rate and unavailability for less than 1 minute/year. Characteristics of paths such as routing via a particular network element, or implementation using a particular technology are not features, because the client cannot detect those characteristics. Features may apply to particular terminations of a path or installed on connections, which often requires feature values. The feature Maximum Bit Rate has a value specifying what the maximum bit rate is, for example Maximum Bit Rate = 256 kb/s. A feature with values applied to a connection is referred to as an *installed feature*.

A *path* is provided by a network and is fully characterised by the installed features of the path (the *path features*), a set of *terminations* exposed to the client and a set of installed features for each termination (the *termination features*). A path may be permanent, that is the ability to transmit exists at all times after the path is established by a connection manager, until it is torn down by the connection manager. A path may be switched, in which case there are two phases, 'configuration' and 'signalling'. The signalling phase initiates and finalises the ability to transfer data. Signalling emanates from network equipment connected to the path. The configuration phase is performed by a connection manager and establishes the bounds of data transfer that can be requested by signalling. For example, configuration may allow data transfer anywhere within a national network, with speed up to 20Mb/s. This would prevent signalling requesting an international transfer, or a 100Mb/s transfer.

A path typically has two terminations, but may have one or many. Examples of paths are ATM PVCs and SVCs, SDH connections, or customer access networks (ie. local loop). The term path as used herein includes the ITU-T concepts

of connection and trail, as well as further concepts such as Switched Virtual Connection.

A *network* represents the ability to manage paths and is used to create new paths and list existing paths. Paths are always totally contained within exactly one network. A network may be conceptualised as a factory of paths, and a collection of the paths that it has created. In is also a collection of the terminations at which the paths will or could be manifest. Example networks include an ATM switch, a Main Distribution Frame, a SONET ring, a ATM domain manager, a regional SDH network manager. The term 'network' includes the ITU-T concepts of network, sub-network and network element.

A network is typically implemented by calling on the services of other networks, termed *sub-networks*. For example, an ATM network may use the services of a DSL and Core ATM network. The term 'sub-network' may imply a client-server relationship between the network and the sub-network. Generally, there is nothing inherent in a network that makes it a sub-network. All sub-networks are fully fledged networks in their own right. Therefore all the properties and functions of networks are also properties and functions of sub-networks

A *termination* is where a path is, or may be, manifest to the client of a network. A termination can also include a grouping of terminations. A termination grouping may or may not be capable of establishing paths. Example terminations may be an physical port, an ATM VPI on a physical port, or a cable pair at a customer's premises. The term 'termination', includes the ITU-T concepts of trail termination point, connection termination point and access group. A termination can participate in a finite number of paths, typically one, but potentially more.

A path in a network will have one or more (usually two) terminations. Single termination paths may represent loop-back and multiple terminations may represent multiple drop (for example CSMA) or a closed user group (for example a voice private network). Paths may share terminations, this may express a multi-serving capability (such as the set of customers using a billing server).

<u>Connection Manager</u>

The connection manager 35, as depicted in FIG 2A, presents an architecture for assembling a working network management system. The core software 37 provides, in one embodiment, connection model abstractions that can be configured

to reflect the characteristics of the particular network equipment deployed by the network owner. The operative connection model 36, once configured, will substantially reflect the business and engineering policies of the network owner, in other words the knowledge that a human operator would apply if they were performing the connection manager functions manually. The core software 37 assumes that the interface to the network supports the connection model 36, preferably expressed in CORBA.

The network adaptors 38 are developed, typically using stack products, such as those provided by Vertel or Hewlett-Packard, in order to provide simple interfaces into complex protocols such as CMIS or TL/1. The service adaptors 39 provide an interface between the network's service management layer OSS. Existing operation support systems generally have a proprietary interface, although there are some emerging standards including the US Federal Communications Commission's "Gateway". Printed paper or a character terminal are common interfaces. The deployed connection manager 35 preferably has an adaptor to automate the interface between the service management layer 20 and the core software 37.

Distributed Object Model

As the connection manager is a network layer manager, it is only concerned with modeling network-level concepts. The first network level concept is "connection". The connection model 36 of the embodiment is a distributed object model, preferably expressed in CORBA interface definition language (IDL). In accordance with the concepts introduced earlier, there are three types of objects in the model, namely:

(i) path objects that represent connections;

(ii) termination objects that represent where the connections are physically manifest; and

(iii) network objects which are the fabric that can create connections.

Network Objects

The network object is a container of path objects and termination objects. Network objects form a hierarchy, where some network objects are superior to others. Network objects will typically form a strict containment hierarchy, though the connection manager allows any non-cyclic structure. Network objects can

represent: individual network element instances, groups of network elements organised by some owner determined criteria, such as geographic domains or functional domains; sub-networks that are managed by some other NMS, such as a vendor NMS; cross-domain networks that aggregate several domain network objects, such as those identified 40A, 40C and 40T in FIG. 1.

Network objects support the following operations: listing the capabilities of the network object; listing the characteristics of the paths that the network objects can create; creating paths having specified terminations and features; previewing path creation; searching for paths, terminations and sub-networks having specified characteristics. Network objects may be configured as follows: assigning identity, description, meaning; defining the relationships between the network objects (for example, a containment tree structure); defining the connections between subordinate network objects; and the characteristics of the paths they can create.

Path Objects

Path objects represent the connections formed by network objects. They correspond to some real-world connection concept. This could be for example:

(i) a physical connection, such as a bearer distribution frame;

(ii) a switched connection, such as an ATM virtual circuit; or

(iii) some abstract relationship, such as the relationship between a customer and their Internet service provider (ISP).

A path object is always contained within one network object. When network objects form a hierarchy, a network object may implement that path by delegating portions of the implementation to sub-paths in its subordinate networks. Paths are characterised by terminations and features. Terminations describe where the path is manifest, features describe externally visible characteristics. A path generally has two terminations.

A feature has a name and optionally a value. Features are applied to either the path itself, or terminations on the path. This permits termination-specific features to be modelled - as required for asymmetrical paths.

Paths support life-cycle type operations. This allows for several levels of completeness of the path's implementation. The typical levels of implementation of paths are:

(a) *design* - the path consumes no resources, other than those minimally needed to record its characteristics;

(b) *reserve* - the path is fully implemented, except the last step which would enable service;

(c) *installed* - the path is implemented into the equipment to enable service; and

(d) *deleted* - the path no longer exists, but the memory of it is kept for audit purposes.

Paths have a cost, which represents the amount of resource required to implement the path. The cost allows a client to rationally choose between several candidate paths, each of which is capable of supporting their needs. Path objects support the following operations: deletion; changing the features, terminations or implementation completeness; preview operations for the above; and listing the path attributes.

Termination Objects

Termination objects represent where path objects are (or may be) manifest. They correspond to some real-world concept for example: a physical termination, such as a cable; one channel multiplexed over some bearer such as an ATM virtual circuit or SDH container; a grouping of multiplexed channels, such as an ATM virtual path. A termination object within one network object. A network may express an effectively infinite number of terminations, for example an ATM network may model each VPI/VCI as a termination. Even coarser grained modelling than the ATM example will have large numbers of terminations.

Termination objects support the following operations: describe the termination; find the lowest cost free termination capable of supporting a particular set of features.

Concepts of Cost

When the core software is implementing a path, or changing an existing path, it may have several alternate methods. Each alternate will require a certain amount of the network owner's or service provider's equipment resource. For example, bandwidth on a optical fibre, dedicated use of a port card, or share of switch capacity. The core suitably implements a path using the alternative that requires the least resource. To allow the connection manager to determine least

resource, the core software uses the concept of "cost". Each candidate path has a cost and each candidate termination has a cost. The connection manager suitably makes the simple choice of 'least cost'. The power comes from the meaning assigned to, and the method of calculating the cost.

Network objects close to the service layer typically have a huge number of candidate paths. One approach that such an object could use, is to execute the preview-path-creation operation on for each of the candidate paths, then choose the one that has the lowest overall cost. This direct approach is practically infeasible when, as is typical, there are multi-millions of candidate paths. To bypass this practical difficulty, the connection manager implements the concept of cost modelling. A cost model is a way for a network's client to efficiently predict the cost of paths. This allows the client to check the millions of options, without doing millions of requests.

Cost Model

A cost model preferably predicts the cost of paths based on termination groups, rather than individual terminations. It supports feature-dependent costs. Cost models may be arbitrarily complex and precise. For example, a highly precise model would specify the cost for paths between each termination group pair. A coarse model would specify a single cost for all paths. Intermediate models that exhibit a arbitrary mixture of termination dependent cost and fixed cost may also be supported.

A cost offer is a named cost model that applies for a specified period of time. A cost offer is the mechanism by which a network exposes the cost model for its paths. As a cost offer includes a validity time, clients can restrict the number of enquiries for cost model that they make. The present embodiment of the connection manager supports validity times from the order of seconds upwards - shorter times need higher computing resource.

FIG 2B is a representation of a connection manager 60 of a further embodiment showing the interaction with service providers 61, 62 in response to a requirement issued by a client 63 for a connection in a communications network. Each service provider has a plurality of paths 64, 65 available in the communications network. The connection manager 60 includes a connection model 66, 67 which indicates functional features supported by each path, along with

locations of terminations for the paths in respective sub-networks. The connection manager 60 further includes a cost model 68 that is associated with the connection model and exposes the cost of using the functional features to the client 63. In a preferred arrangement the cost model is transferred 71, 72 from a service provider into the connection manager 60. The connection manager processing means 69, operates in response to the client requirement to first identify from the connection model 66, 67 candidate paths relevant to the specified locations and, secondly to determine on the basis of cost exposed by the cost model 68 an optimal selection from the candidate paths, which suitably meet a 'least cost' criterion. Further details about a preferred cost model, explained with reference to a network fragment, follow.

There are two options available for determining costs for a network object, namely:

(i) *fixed cost* - where a configured cost is returned; and

(ii) *mapped cost* - where a value for cost is returned that is derived from the costs of its subordinate networks.

The mapped cost option converts the units of cost and features in each subordinate network into the units of cost and features for the present network.

The mapped cost offer is a particularly powerful mechanism, as it allows a network to express a very precise and up-to-date cost model (that is, one that reflects details of its subordinate networks) for zero operator cost. In general, mapped cost is a very effective way to transferring rational decision making capability from subordinate networks to superior networks. This is necessary because the subordinate networks, close to the equipment, understand the equipment-related intricacies, while the superior networks, close to the service layer, have a sufficiently broad view to perform network-wide optimum resource allocation.

The cost model 68 of the embodiment, which uses a data structure in the form of a traversable graph of cost nodes, includes three major aspects. Each aspect is designed to solve cost-related problems in the different stages of the management application development. The aspects of a preferred modelling process are:

- Cost graph creation - a cost graph notation is defined. This notation can be used during the design stage to assist system integrators and network engineers to analyse the cost model at different network levels.
- Cost model specification - during specification stage, the core software can be used to translate the cost graph representation of the network cost model to the format that can be loaded into a connection manager system.
- Route selection algorithm - based on the internal representation of the cost model, the route selection algorithm and the cost-based routing algorithm are used for path creation.

Here the term route means a set of sub-paths that together implement a path between terminations at two selected locations in the network.

Cost Graph

A cost graph is a graphical representation of a cost model. In some cases, a cost model can be represented by a single cost graph; in some other cases, a number of disconnected cost graphs are needed to represent a single cost model. In order to understand the cost model and how it may be used to assist the selection of a path route, an example network is used. The physical architecture of the example network is illustrated in FIG.4.

The physical network contains a number of access devices, such as multiplexers, marked as A1 to A4; a number of edge switches marked as E1 to E3 and two core switches, C1 and C2. These physical components form two logic groups: an access domain, which provides the customer access front end to the network, and a core domain, which provides the communication back bone of the network. Each access device has a number of customer termination points, such as A to H, and is linked to an edge switch. An access device cannot switch, that is, no path can be created between two terminations connected to the same access device without going out to an edge switch. In the above example network, all possible paths contain one of the following sub-paths: A_i-E_j-A_k, A_i-E_j-E_k-A_{ln}, A_i-E_j-C_k-E_l-A_m, A_i-E_j-C_k-C_l-E_m-A_n. (i, j, k, l, m, n = 1 to 4). Using the connection model discussed earlier, the network can be modelled as a cross-domain network containing two domain sub-networks, an access domain sub-network and a core domain sub-network. Each sub-network contains a number of items of equipment as

its sub-networks. A view of the connection model for the network is illustrated in FIG. 5, and it will be appreciated that this network could itself be a sub-network of the larger network illustrated in FIG. 1.

The cost model of each network can be represented using a cost graph or a set of cost graphs. A cost graph contains the following three basic elements, as follows:

"Cost node" - the basic element in a cost graph. Each cost node has a name and the following information associated with the cost node:

- a set of features this cost node supports, derived from the connection model;
- the cost of using these features; and
- the delay in implementing these features.

"Termination" – a special node in the cost graph indicating the potential starting and ending point of a path. It could be a single termination, although typically it is a termination group.

"Edge" – a line between a termination point and a cost node or between two cost nodes.

An important aspect of constructing a cost graph is to identify a set of cost nodes for the network. Potentially, any network resource or abstract of such resource can be a cost node. Example network resources include network equipment, connections, sub-networks, and even the network itself. Manually building a cost graph to represent a cost model of an entire network is a complex task. Therefore the connection manager allows the cost model of a network to be an aggregation of the cost models of the sub-networks. Hence, the cost model of a network can be composed from a set of cost models of sub-networks or even a cost model of a group of network equipment, with negligible configuration effort. In the example network shown in FIG. 4, a simple cost model can be constructed for each piece of network equipment, such as access devices and switches.

FIG. 6 shows the multiplexer A1 and its corresponding cost graph. On the customer side of A1, there two termination points, A and B. Both A and B can be grouped as a termination group. The access device does not support local switching, so there are is no direct connection between A and B. On the network

side, A1 has a termination a connected to an edge switch in the core domain. Multiplexer A1 can be modeled as a single cost node with two terminations, TG1 (termination group 1 containing terminations A and B) and a. Turning to consider a mulitplexer with reference to FIG. 7. In general, an m-to-n multiplexer has one customer side containing m terminations and one core side containing n terminations. The terminations on each side can be grouped into one group. Such a multiplexer can be represented as a single cost node with two termination groups as shown in FIG. 7B.

The cost model for an edge switch and a core switch is similar to the one for an access device, except that both the edge switch and the core switch support local switching. That is a path can be created from one termination point to itself (it may in fact go through different virtual channels or virtual paths). In the case of an edge switch E1 as shown in FIG. 8A, paths m-E1-m, n-E1-n, m-E1-n, m-E1-q and n-E1-q can be created. To represent this, double edges to the same termination should be used. The cost graph of the edge switch E1 can be represented as shown in FIG. 8B.

Because the physical capabilities of a core switch are similar to that of the edge switch E1, the cost model of a core switch should be similar to the cost model of the edge switch E1. For example, core switch C1 is capable of performing local switching. To represent this, duplicated terminations should be used as shown in FIG. 9. However, a business rule may specify that based on the network architecture given in Figure 1, the local switching capability supported by core switches does not add any value to the path creation, and hence should be ignored during cost modelling. For example, because edge switch E1 supports local switching, a path A1-E1-A2 can be created. This basically eliminates the requirement of having a path A1-E1-C1-E1-A1. To enforce this business rule, the cost model of core switch C1 should really be modelled shown in FIG. 10. This is an example of how, in the cost model, a business rule can override physical capability in the network.

Cost Model Aggregation

Generally a physical network contains a number of sub-networks and for mapped cost models, the connection manager performs the aggregation. In some embodiments, the cost model may be partially mapped as required. If each sub-network's cost model contains only a single cost graph and a link between a

termination of a cost graph to another termination of another cost graph is specified by a system integrator, then connection manager does the aggregation by replacing the terminations and associated edges with a single edge. For example, if a link is specified between the termination q of cost graph E1 and the termination r of cost graph C1, as shown in FIG. 11. The terminations involved in the link q and r become internal terminations (sometimes also referred to as intermediate terminations) of the current network. These terminations will be required by the creation of sub-paths during routing.

If the connections between different sub-networks bear significant cost, then a cost can be specified for the links. In the above example, if the connection between E1 and C1 bears a cost, a new cost node CN_L1 is introduced when aggregating these two cost models, as shown in FIG. 12. If a link involves duplicated terminations (e.g. in the case of support local switching), then the other cost graph (the one without duplicated terminations) should be duplicated and each linked to one of the duplicated terminations. For example, a link between termination a of cost graph for A1 (see Figure 6B) and termination m in cost graph for E1 (see Figure 8B) will lead to the aggregated cost graph illustrated by FIG. 13.

Applying these aggregation techniques to all cost models in the core domain, the domain cost model shown in FIG. 14 can be obtained. Whilst FIG. 15 illustrates the cost model for the network obtained, after accounting for duplicated terminations, for the cross domain corresponding to the physical network shown in FIG. 4.

Cost Based Route Selection

The method for route selection involves creating an aggregate cost graph of the relevant sub-networks, as described above, and keeping a record of which sub-network is responsible for each cost node. The second part of the method involves finding the lowest-cost of path through the cost nodes between terminations available at the desired locations. A system for allowing exclusion of certain types of sub-networks may, in some cases, be used to "filter" the cost model prior to using the route selection method of the embodiment.

A routing method which may be used to select a route with the lowest cost will now be described. During the selection process, the feature set associated with each cost node provides another level of filtering. If the required features are not

supported by a sub-network, then any paths involving that sub-network are not selected. In the following discussion, in order to describe the routing method clearly, a cost graph is re-shaped according to the starting location (or termination group) specified in a path creation request. For example, to create a cross domain path from termination point E to H as indicated in Figure 4, the cross domain cost graph in FIG. 15 can be re-shaped as a tree structure with the starting termination group as the root, and the ending termination group and other terminations as the leaves. The re-shaped cost graph is shown in FIG. 16. Such shaped cost graph shows all the possible routes starting with the given termination. If multiple routes from the starting termination to the ending termination exist, then the ending termination will appear more than once.

The diagram in FIG. 17 illustrates one form of the path selection method. Starting from C1, which is the cost node directly linked to the starting termination A, a first wave is generated. The wave contains all the cost nodes that support the required feature and are directly connected to C1. Three cost nodes involved in the frontage of the first wave are C2, C3 and C4. From the starting termination A to each frontage cost node forms a candidate route. By adding the current sub-total cost of each candidate route, a lowest-cost candidate route (from A to C2) is selected. Progress will only be made with the currently selected route by pushing the wave one step further to form a second wave. The frontage cost nodes of the second wave include two groups:

- all frontage cost nodes of the unselected routes in the last wave, e.g. C3 and C4; and
- all cost nodes directly connected to the selected cost node in last wave, e.g. C5 and C6.

Here it is assumed that both C3 and C4 support the required feature.

The above process can be repeated until the paths from A to B with the lowest cost are selected. In the example the selected route is A-C1-C2-C6-C10-H. The cost of the selected route is 7, which cost is lower than the current sub-total of any other single candidate route. Applying the method for route selection from E to H in FIG. 16, a route from E-CN_A3-CN_E2- CN_E3-CN_A4-H will be selected as follows with reference to FIG. 18. Apart from the feature parameter, that may

affect the route selection, another parameter "delay" may also affect the selection of a route. The routing algorithm can also be optionally arranged to reject paths having delays greater than a required maximum delay.

Once a route is selected using the cost model, it provides a reference of how the required connection can be created in the physical network. If the selected route only involves one sub-network the connection can be created over the sub-network. If the route involves more than one sub-network, then a number of paths need to be created over the relevant sub-networks. In order to make the necessary connections, the current network must find the intermediate terminations at the boundary of each sub-network. These terminations are those used to form links, as discussed above in relation to FIG. 11.

It will be appreciated that implementations of the cost model, other than a selection method that uses static data in nodes on a traversible graph as described above in relation to the preferred embodiment, are possible. In general terms, the selection method of the embodiment is one implementation of a cost model wherein a delegate offers a data structure that is capable of representing complex or subtle cost predictions when interpreted by a method pre-agreed by the delegate and delegator. Though such data structures are complex, they are not general purpose, in the sense of being Turing machines. This means that there will always be some cost predicates that cannot be conveniently represented in the model.

An alternate approach is to pass a piece of data that is the program for a Turing machine. The delegator and delegate must still agree of the semantic of the data (that is, the implementation of the Turing machine). However there will no longer be intrinsic limitations of the ability to represent any cost model. For example, it is unlikely that a data structure approach could model a cost prediction that involves the calculation of B-spline interpolation (unless the data structure designer foresaw that need). The Turing machine approach does not suffer such a limitation. A practical implementation of the Turing machine approach is to agree on an implementation that is well understood in the industry. One such example is to use a Java™ Virtual Machine implementation, and the cost model is then transferred as a sequence of Java™ byte codes.

The cost model allows the connection manager to expose or publish a comprehensive estimate of what a path between two locations will cost, without the

client having to make a vast number of queries about the cost of each possible choice. It is the service provider's or network owner's choice as to how comprehensive a cost model is provided. They may publish a detailed cost model without exposing the underlying structure of the network.

By automating the routing and configuration of connections across complex networks, the connection manager substantially reduces the need for manual management at the network and element levels. Connections can be provisioned in real time and the connection manager will scale to process increasing volumes of new connections as broadband communications networks grow.

The object oriented approach to modeling aspects of the network in the connection manager, wherein the abstract connection model is differentiated from the connection model instantiations result in a high degree of reuse of clients and servers. This approach also allows for, but does not enforce, very flexible client and server implementations, which can match a rapidly changing business scenario.

Throughout the specification the aim has been to describe the preferred embodiments of the invention without limiting the invention to any one embodiment or specific collection of features.

CLAIMS

1. A connection manager for selecting paths, from a plurality of paths available from service providers in a communications network, to route broadband traffic in the network, wherein the connection manager includes:

(a) a connection model indicating functional features supported by each path in the network and locations of terminations for respective paths;

(b) a cost model associated with the connection model that exposes to clients the cost of using the functional features for each path; and

(c) processing means, operated in response to a client requirement for a connection with desired features between two locations in the network, to -

(i) identify, from the connection model in light of the desired features, suitable candidate paths for routing communications traffic between the two locations and

(ii) determine, from the candidate paths and on the basis of cost exposed by the cost model, an optimal selection of paths connecting said locations.

2. The connection manager as claimed in claim 1 wherein the functional features indicated by the connection model include one or more of the following:

(i) communications protocol;

(ii) transmission rate;

(iii) availability of the path; and

(iv) average error rate.

3. The connection manager as claimed in either claim 1 or claim 2 wherein the cost exposed by the cost model reflects the resources required to implement a path having a particular set of features.

4. The connection manager as claimed in any one of claims 1 to 3 wherein the path cost is determined in accordance with one or more of:

(i) number of network elements involved in the path;

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(ii) reduction in network capacity experienced in implementing the path; and

(iii) funds required to implement the path.

5. The connection manager as claimed in any one of claims 1 to 4 wherein the cost model represents path cost as a data structure which is interpreted by the processing means.

6. The connection manager as claimed in claim 5 wherein the data structure comprises a graph of cost nodes and each node specifies the cost of particular features or sets of features for respective paths.

7. The connection manager as claimed in claim 6 wherein the cost nodes in the graph may be either internal for representing links between internal terminations in the connection model or external for the terminations at said predetermined locations.

8. The connection manager as claimed in any one of claims 1 to 4 wherein the cost model represents path cost as code which is executed by the processing means.

9. The connection manager as claimed in claim 8 wherein the processing means for executing the code is an implementation of a Turing machine.

10. The connection manager as claimed in any one of claims 1 to 9 wherein the cost model further exposes to clients the delay in implementing functional features supported by the path.

11. The connection manager as claimed in claim 10 wherein the client requirement for a connection includes a desired minimum delay which is utilised as a further basis for determining the optimal selection of paths.

12. The connection manager as claimed in any one of the preceding claims wherein individual terminations at the same location that have common attributes are represented as termination groups.

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13. A connection manager for selecting paths from a plurality of paths available from service providers in a communications network to route broadband traffic in the network, wherein the connection manager includes:

(a) a cost model provided by each service provider that exposes to clients the cost of using functional features supported by each path; and

(b) processing means, operated in response to a client requirement for a connection with desired features involving a plurality of terminations in the network, to -

  (i) identify, in light of the desired features, candidate paths for routing communications traffic amongst said plurality of terminations and

  (ii) determine, from the candidate paths and on the basis of cost exposed by the cost model, a least cost selection of paths connecting said terminations.

14. The connection manager as claimed in claim 13 wherein the cost model also exposes to clients delay in the service provider making a path available.

15. The connection manager as claimed in either claim 13 or claim 14 wherein available paths include paths pre-existing in the network.

16. The connection manager as claimed in either claim 13 or 14 wherein available paths include paths that can be created by a service provider.

17. The connection manager as claimed in any one of claims 13 to 16 wherein the cost model exposes usage cost depending on the functional features required of each path by making cost offers to the client, which cost offers are valid for a predetermined time.

18. The connection manager as claimed in any one of claims 13 to 16 wherein the cost exposed by the cost model reflects the resources required to implement a path having the desired set of features.

19. The connection manager as claimed in any one of claims 13 to 18 wherein the path cost is determined in accordance with one or more of:

(i) number of network elements involved in the path;

(ii) reduction in network capacity experienced in implementing the path; and

(iii) funds required to implement the path.

20. The connection manager as claimed in any one of claims 13 to 19 wherein the cost model represents path cost as a data structure which is interpreted by the processing means.

21. The connection manager as claimed in any one of claims 13 to 20 wherein the cost model represents path cost as code which is executed by the processing means.

22. The connection manager as claimed in any one of claims 13 to 21 wherein a cost model is transferred to the connection manager from each service provider.

23. The connection manager as claimed in any one of claims 13 to 22 wherein the client is a superior connection manager and a superior cost model is constructed from an aggregate of cost models transferred by subordinate connection managers.

24. A selection method for selecting paths, from a plurality of paths available from service providers in a communications network, to route broadband traffic in the network, including the steps of:

(a) creating a connection model that indicates functional features supported by each path in the network and locations of terminations for respective paths;

(b) creating a cost model associated with the connection model that exposes to clients the cost of using the functional features for each path; and

(c) processing a client requirement for a connection with desired features between two locations in the network by -

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(i) identifying, from the connection model in light of the desired features, suitable candidate paths for routing communications traffic between the two locations and

(ii) determining, from the candidate paths and on the basis of the cost exposed by each service provider, an optimal selection of paths connecting said locations.

25. The selection method of claim 24 wherein the step of creating the connection model reflects attributes of network elements deployed by each service provider.

26. A method of managing selection of paths from a plurality of paths available from service providers in a communications network to route broadband traffic in the network, said method including the steps of:

(a) creating a cost model whereby each service provider exposes to clients the cost of using functional features supported by respective paths;

(b) processing a client requirement for a connection with desired features involving a plurality of terminations by -

(i) identifying, in light of the desired features, candidate paths for routing communications traffic amongst said plurality of terminations and

(ii) determining, from the candidate paths and on the basis of cost exposed by the cost model, a least cost selection of paths connecting said terminations.

27. The method of managing selection as claimed in claim 26 wherein the cost model is transferred to the connection manager from the service provider.

28. The method of managing route selection as claimed in either claim 26 or claim 27, wherein the client is a superior connection manager and a superior cost model is constructed from an aggregate of cost models transferred from subordinate connection managers.

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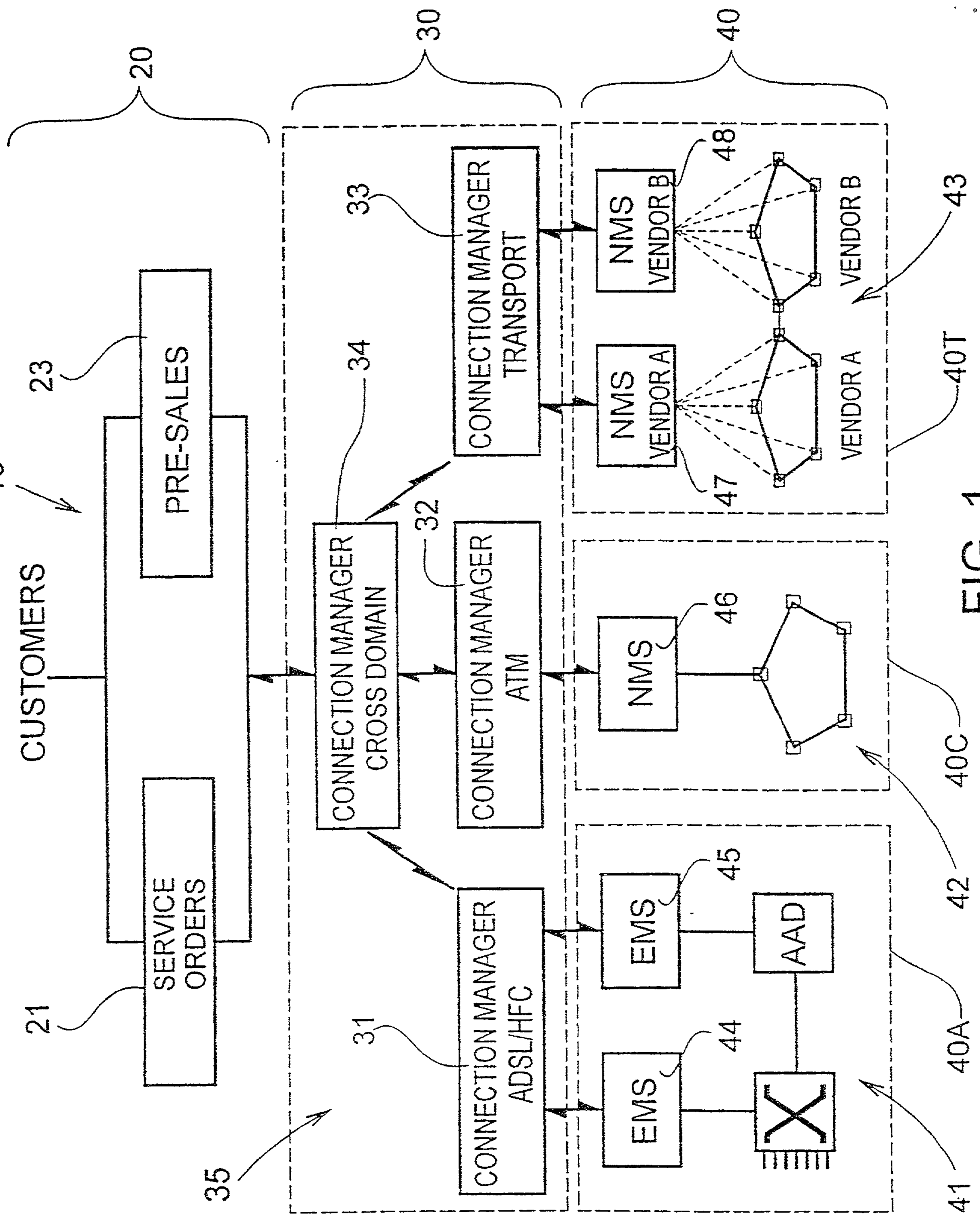

FIG. 1

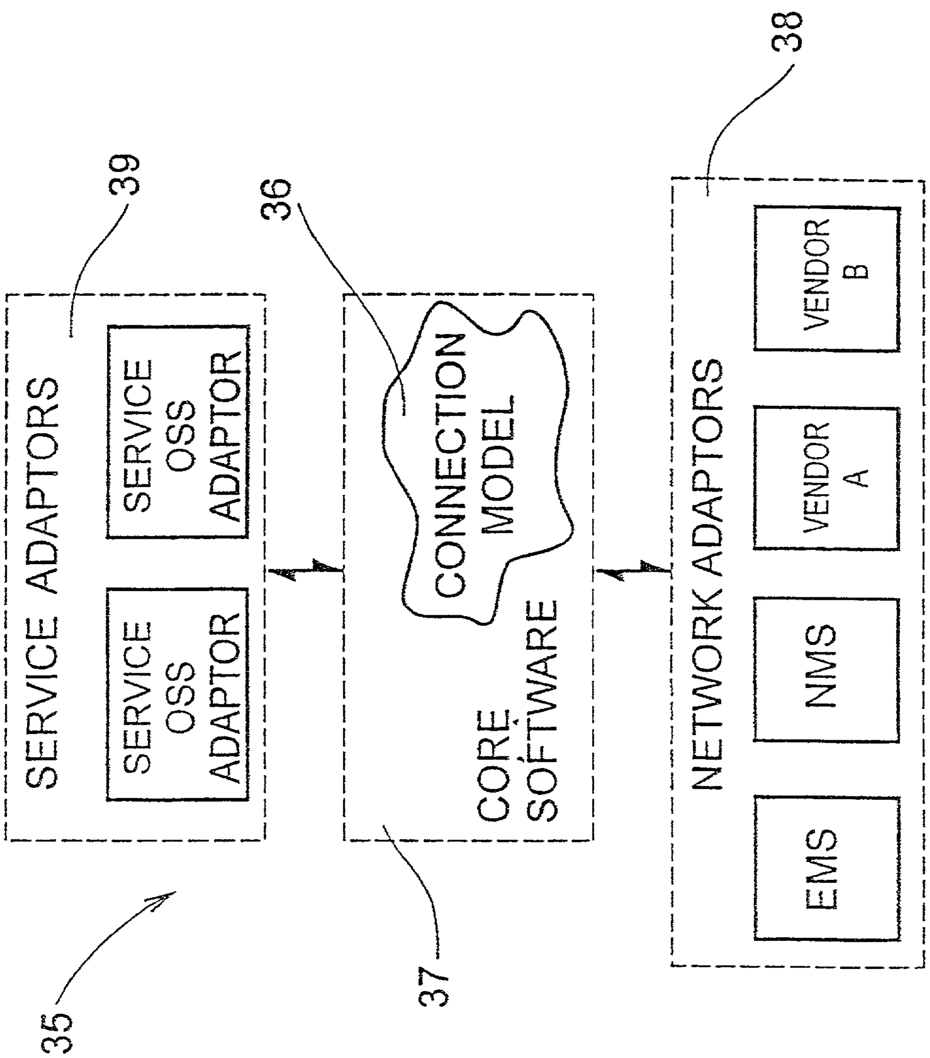
SERVICE ADAPTORS
SERVICE OSS ADAPTOR
SERVICE OSS ADAPTOR
CONNECTION MODEL
CORE SOFTWARE
NETWORK ADAPTORS
EMS
NMS
VENDOR A
VENDOR B
35
36
37
38
39

FIG. 2A

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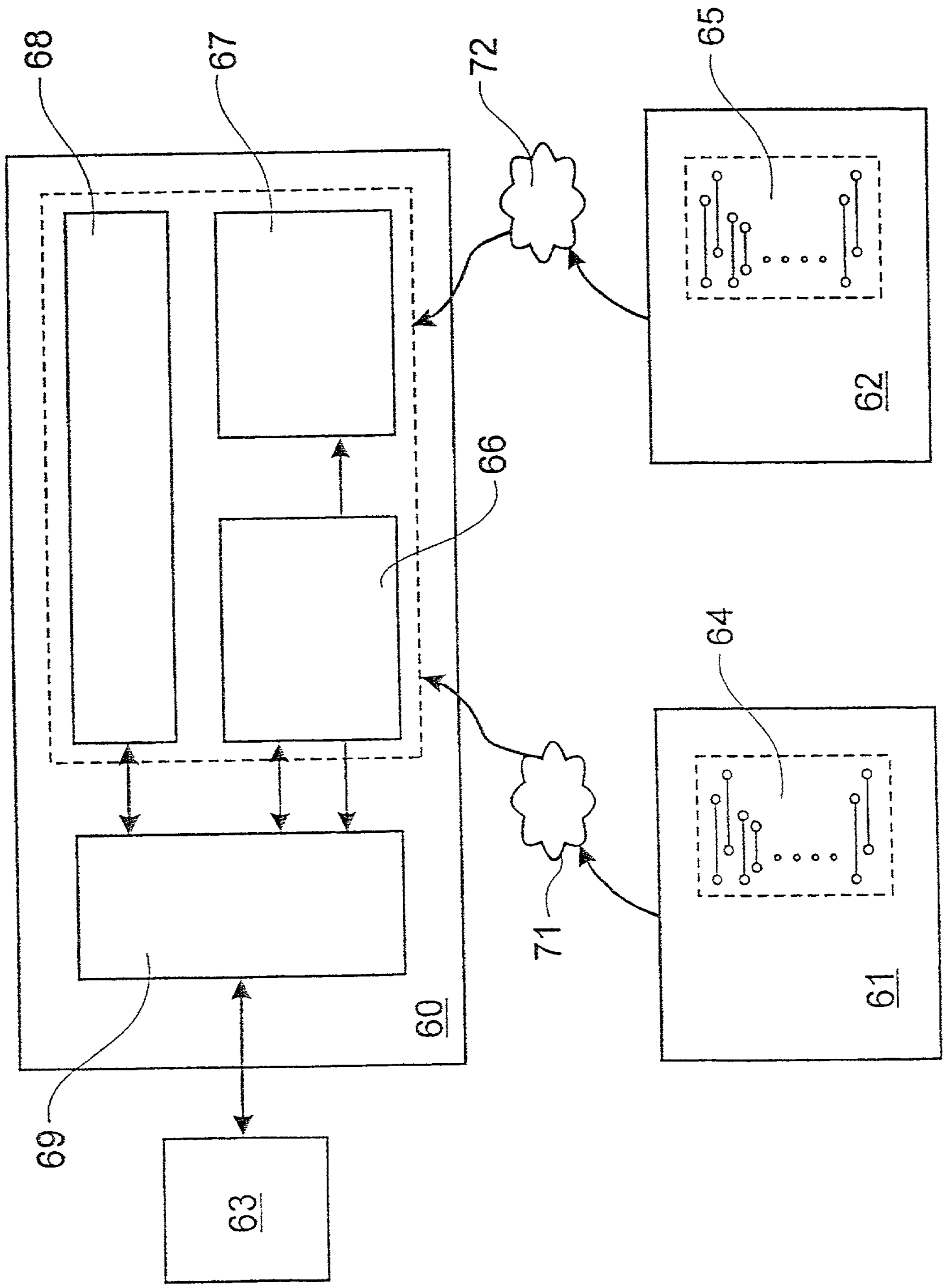

FIG. 2B

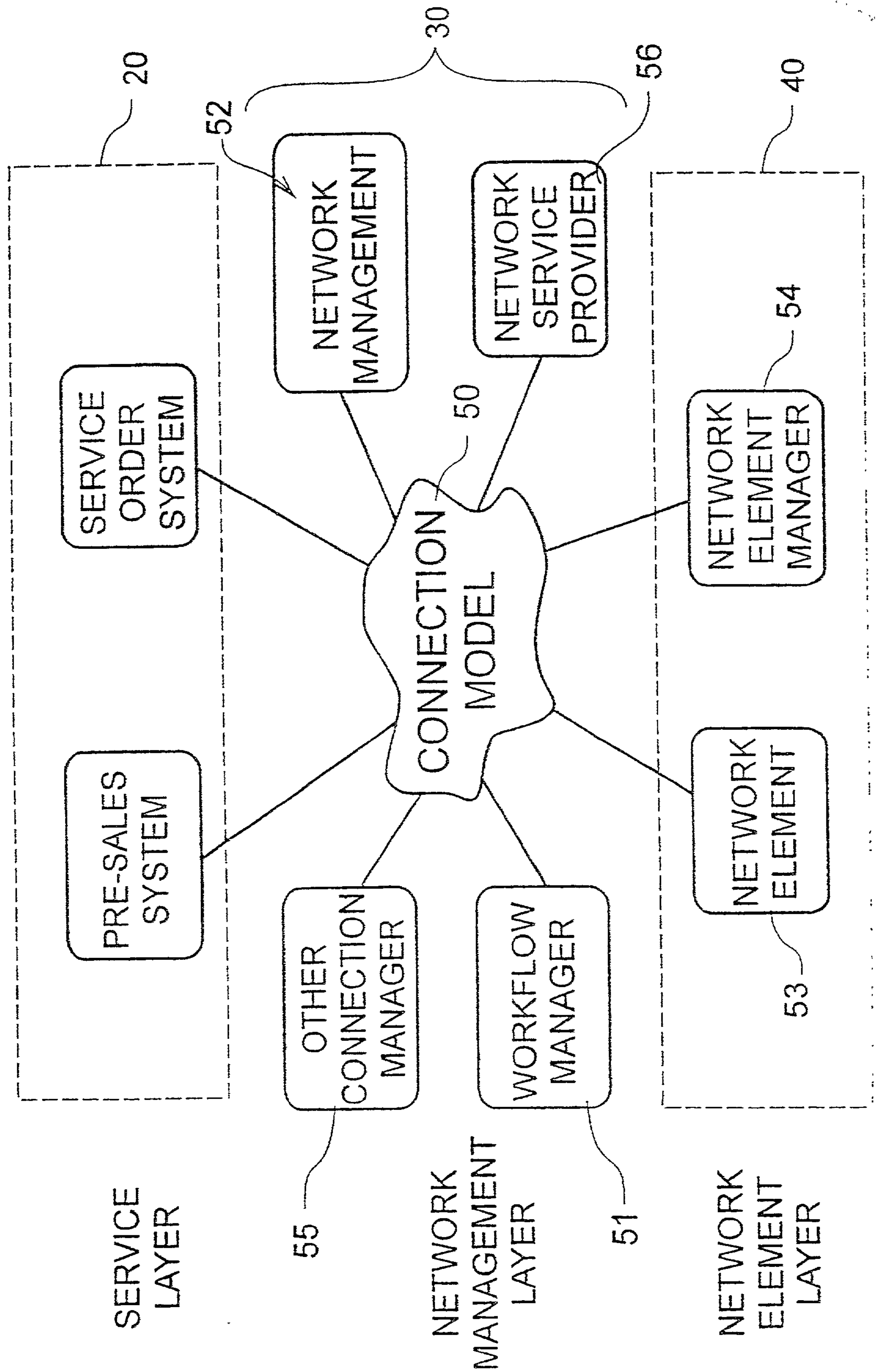
20
30
52
56
40
SERVICE ORDER SYSTEM
NETWORK MANAGEMENT
NETWORK SERVICE PROVIDER
NETWORK ELEMENT MANAGER
54
50
CONNECTION MODEL
PRE-SALES SYSTEM
OTHER CONNECTION MANAGER
WORKFLOW MANAGER
NETWORK ELEMENT
53
55
51
SERVICE LAYER
NETWORK MANAGEMENT LAYER
NETWORK ELEMENT LAYER

FIG. 3

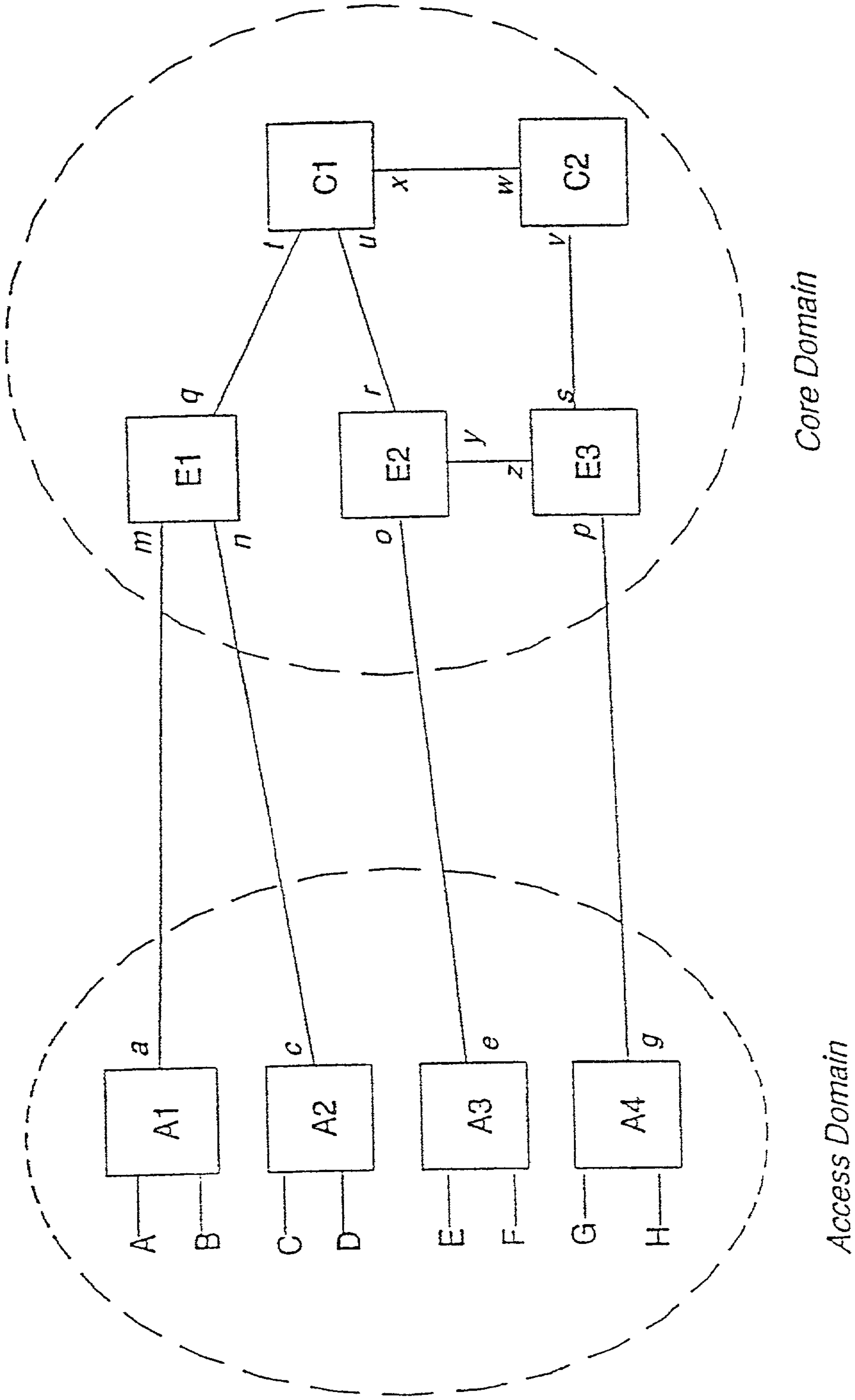
C1
C2
E1
E2
E3
A1
A2
A3
A4
x
w
t
u
v
q
r
s
y
z
m
n
o
p
a
c
e
g
A
B
C
D
E
F
G
H
Core Domain
Access Domain

FIG. 4

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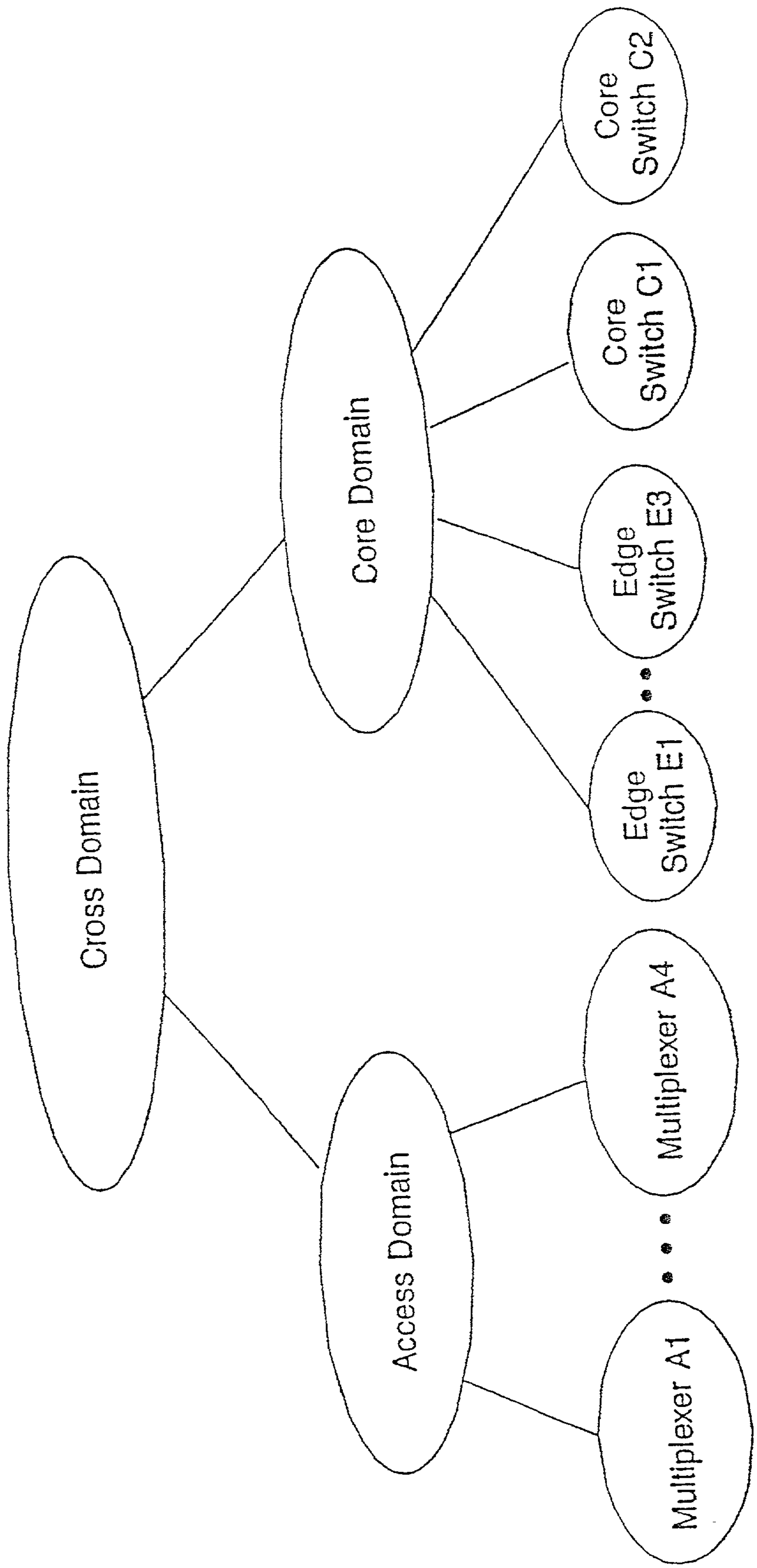

FIG. 5

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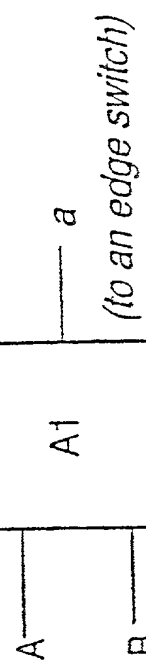

FIG. 6A

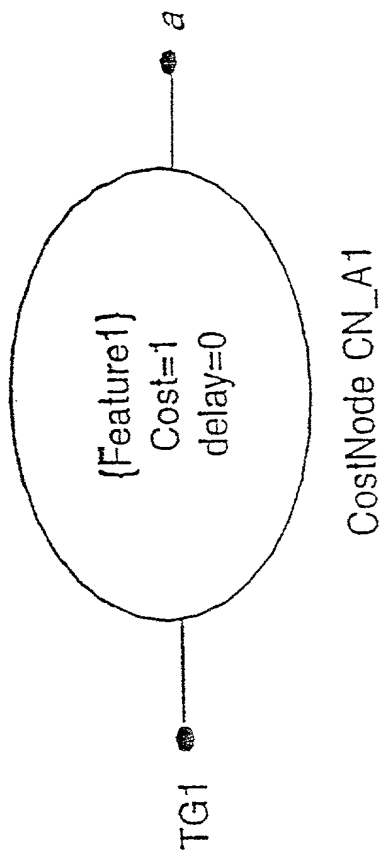

FIG. 6B

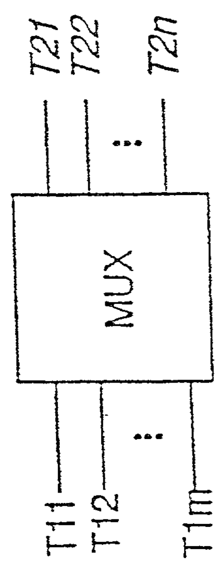

FIG. 7A

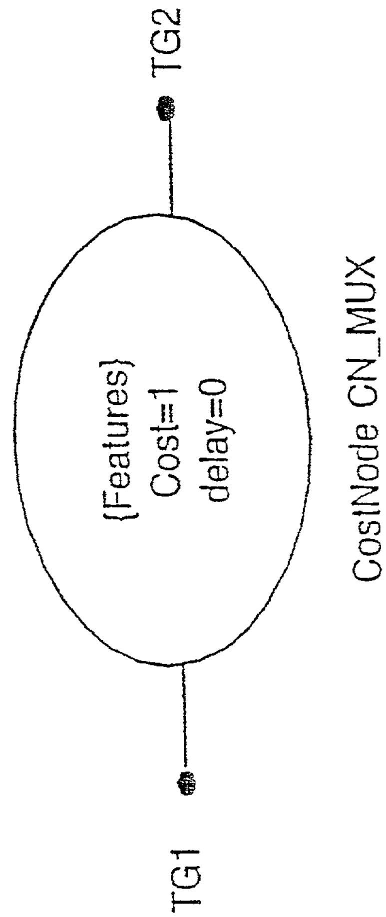

FIG. 7B

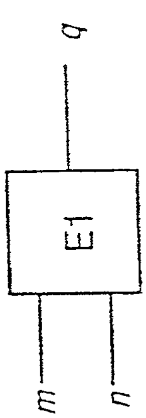

FIG. 8A

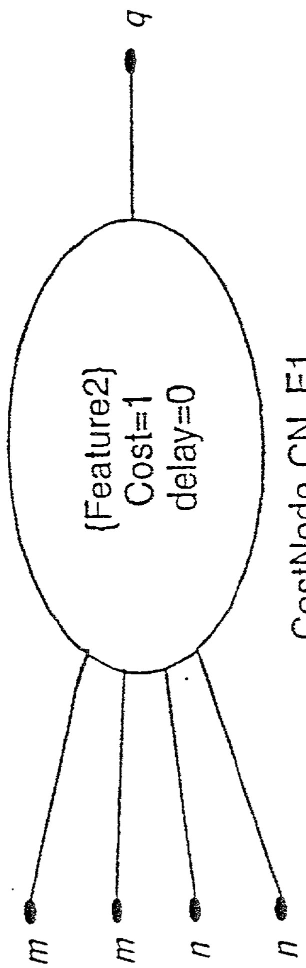

FIG. 8B

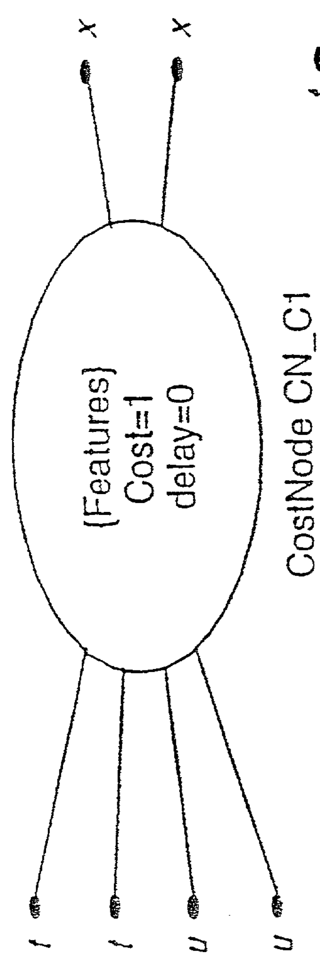

FIG. 9

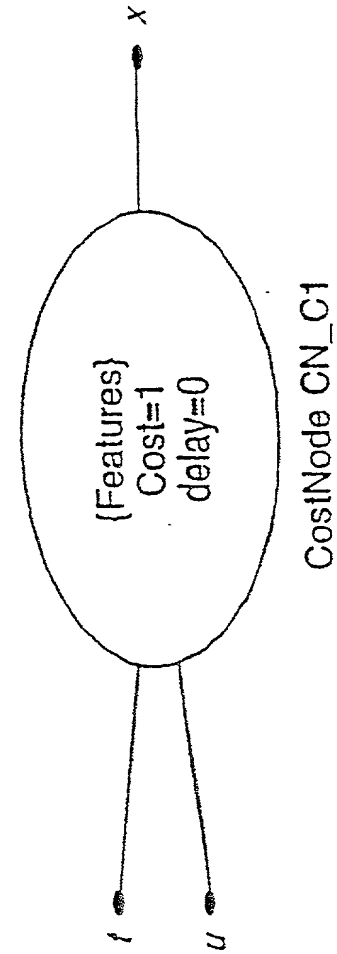

FIG. 10

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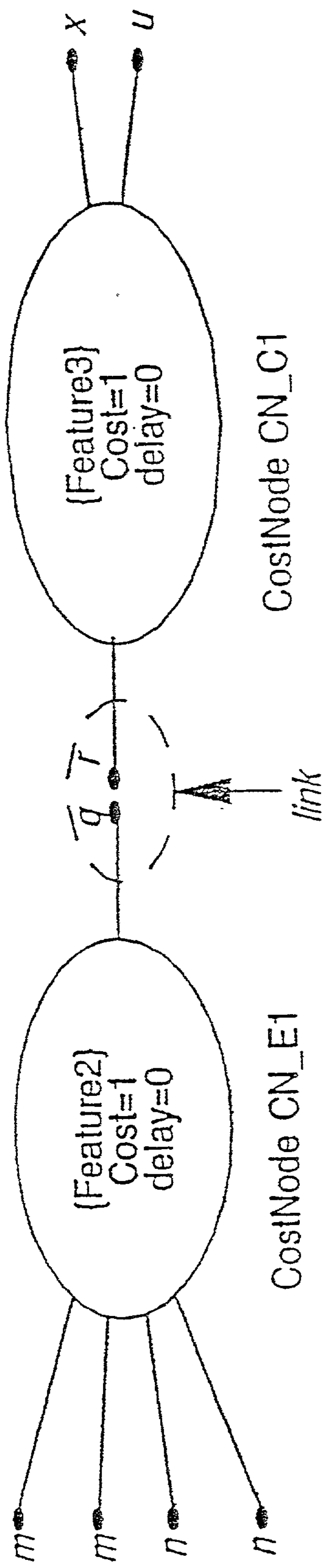

FIG. 11

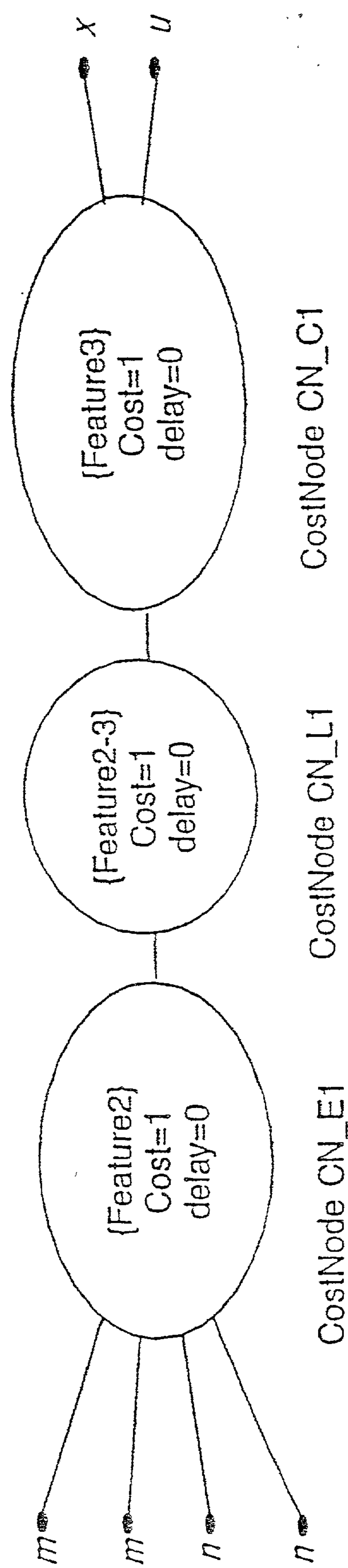

FIG. 12

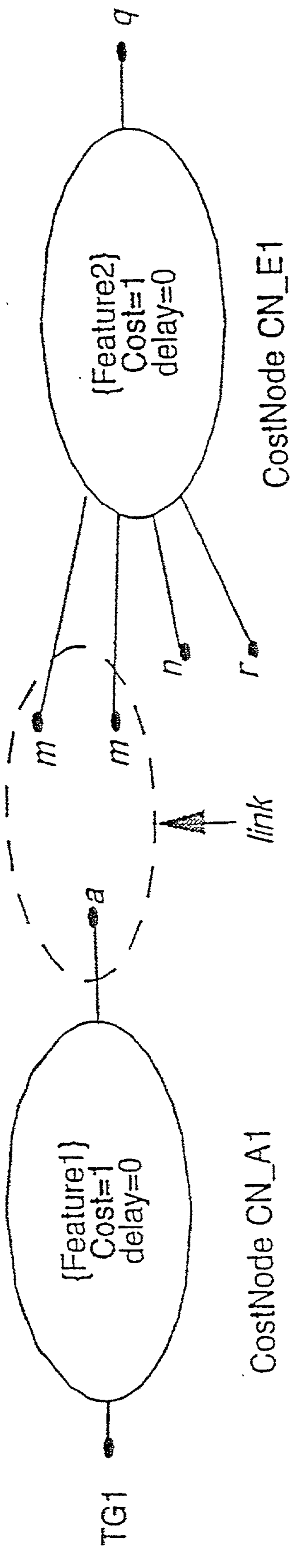

FIG. 13A

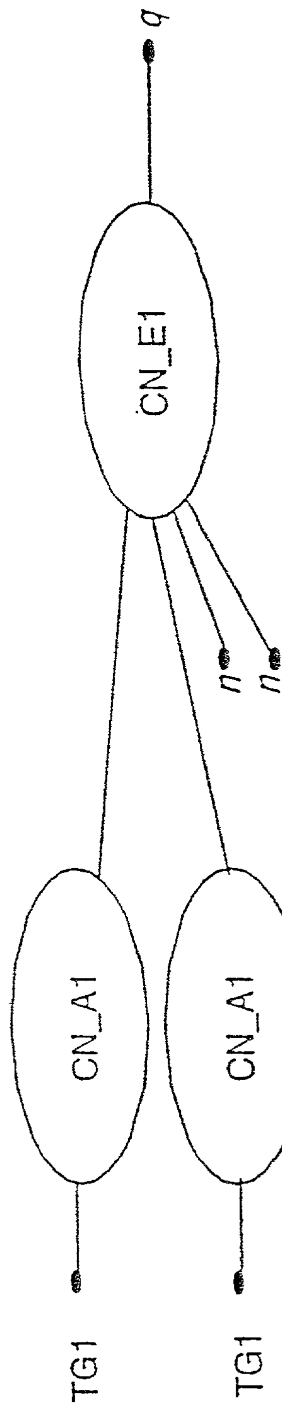

FIG. 13B

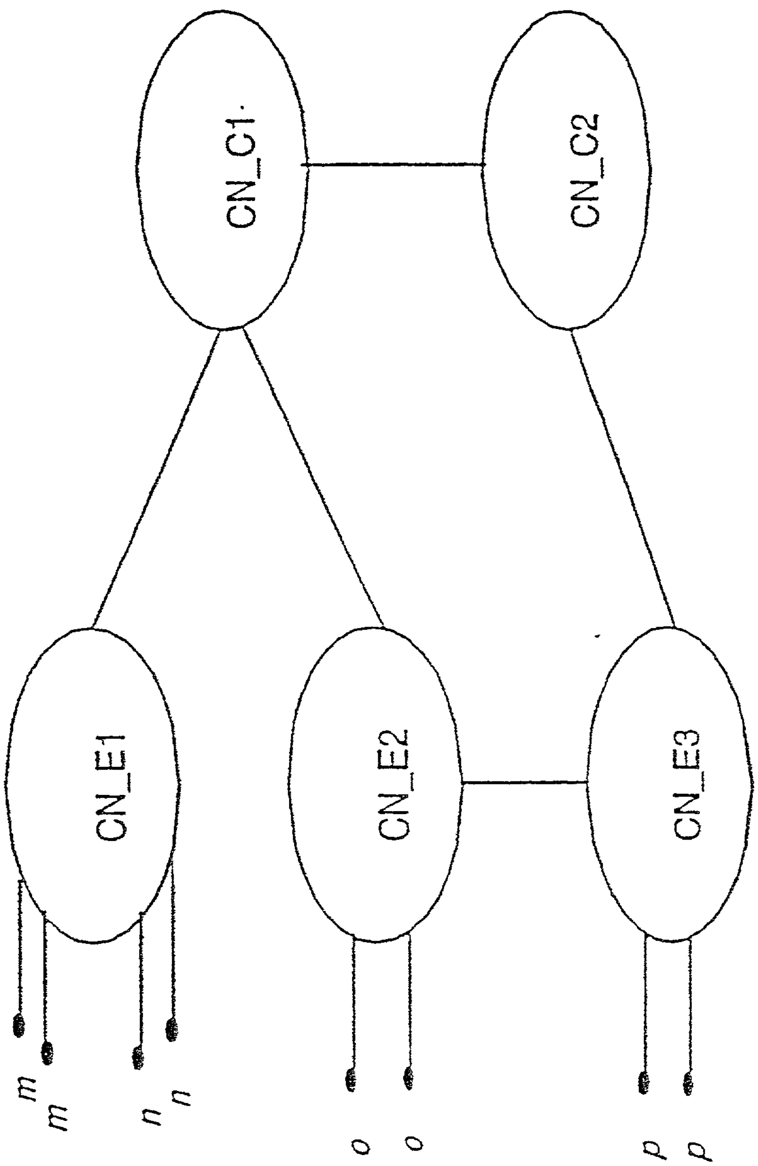

FIG. 14

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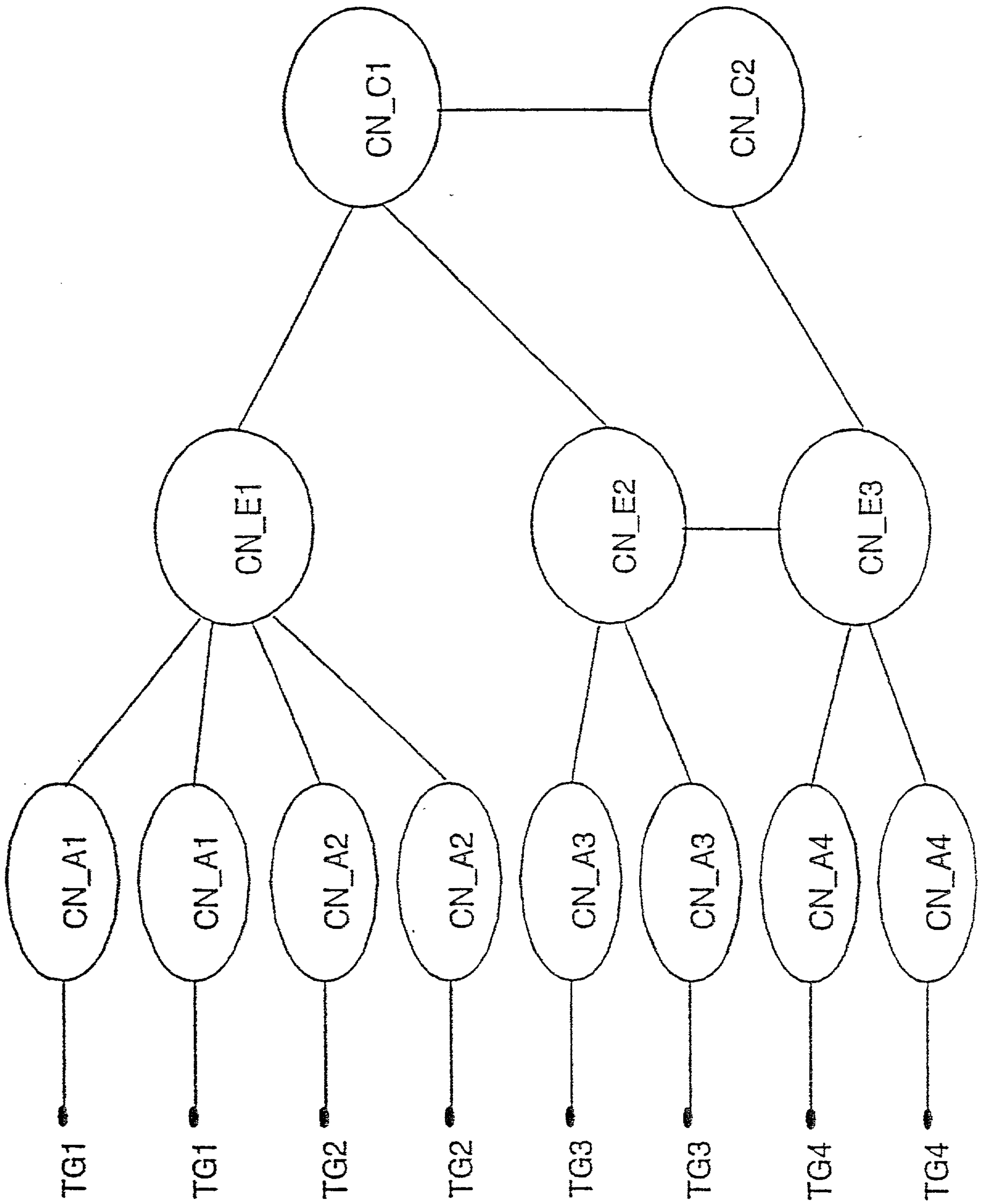

FIG. 15

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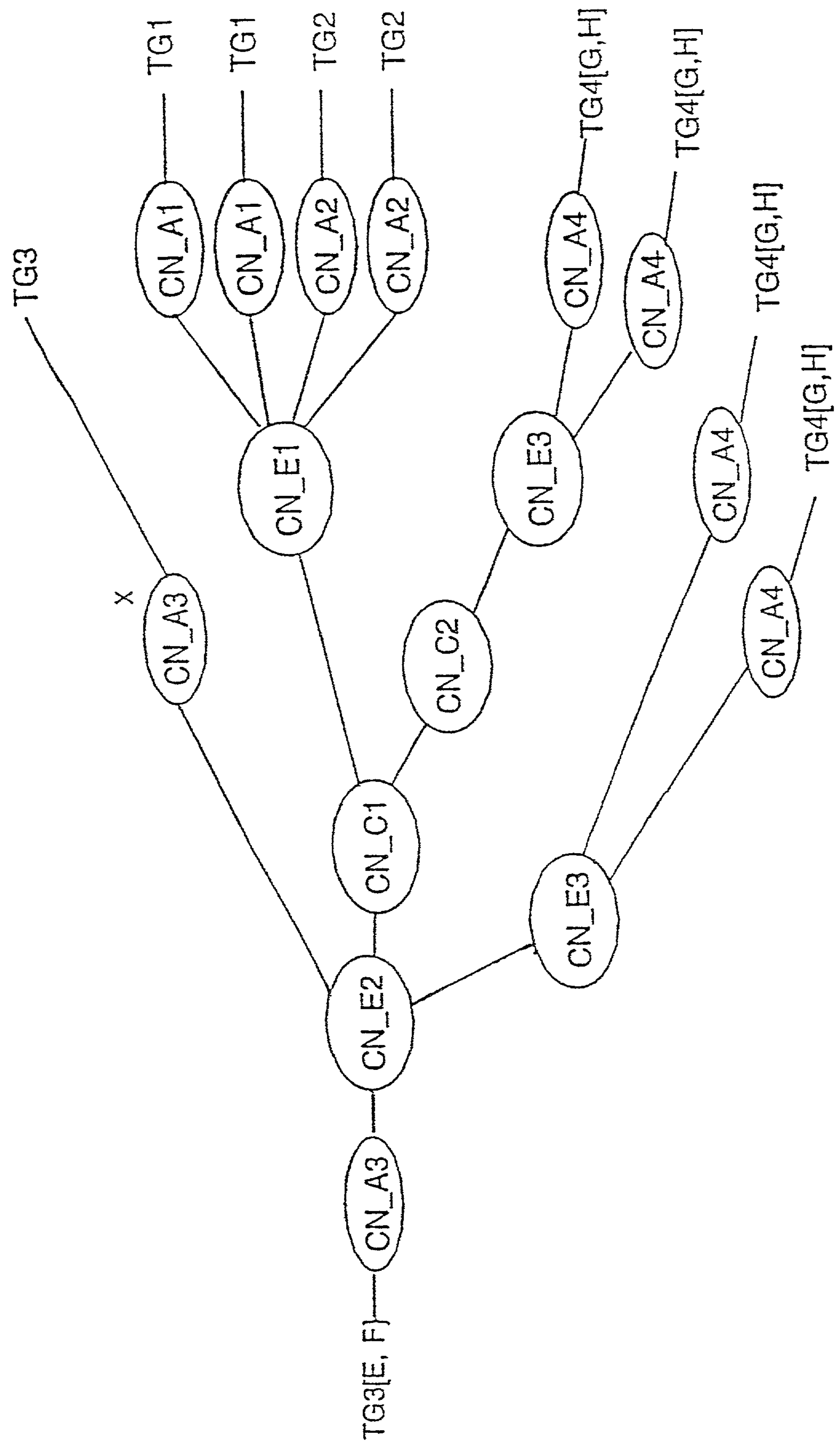

FIG. 16

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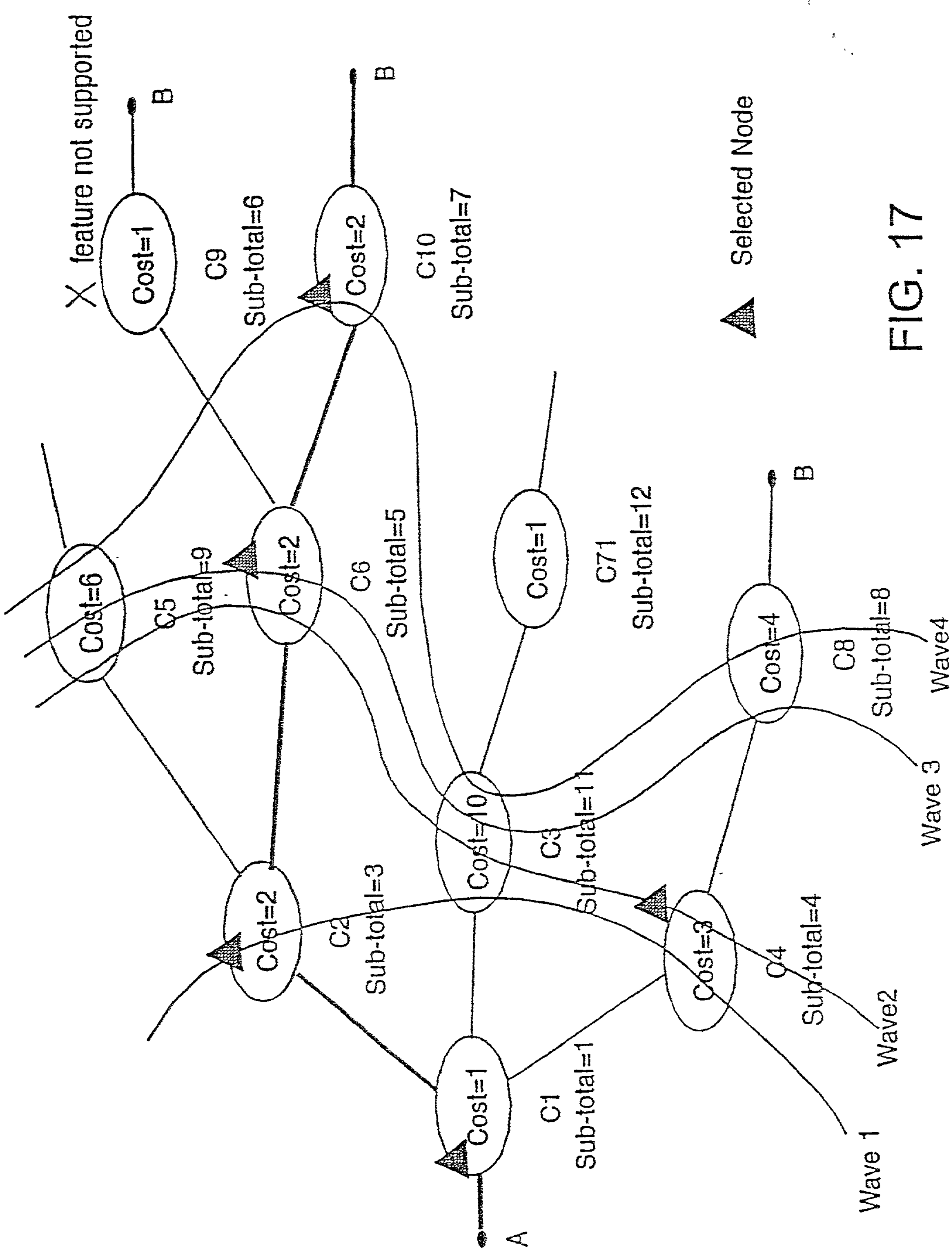

FIG. 17

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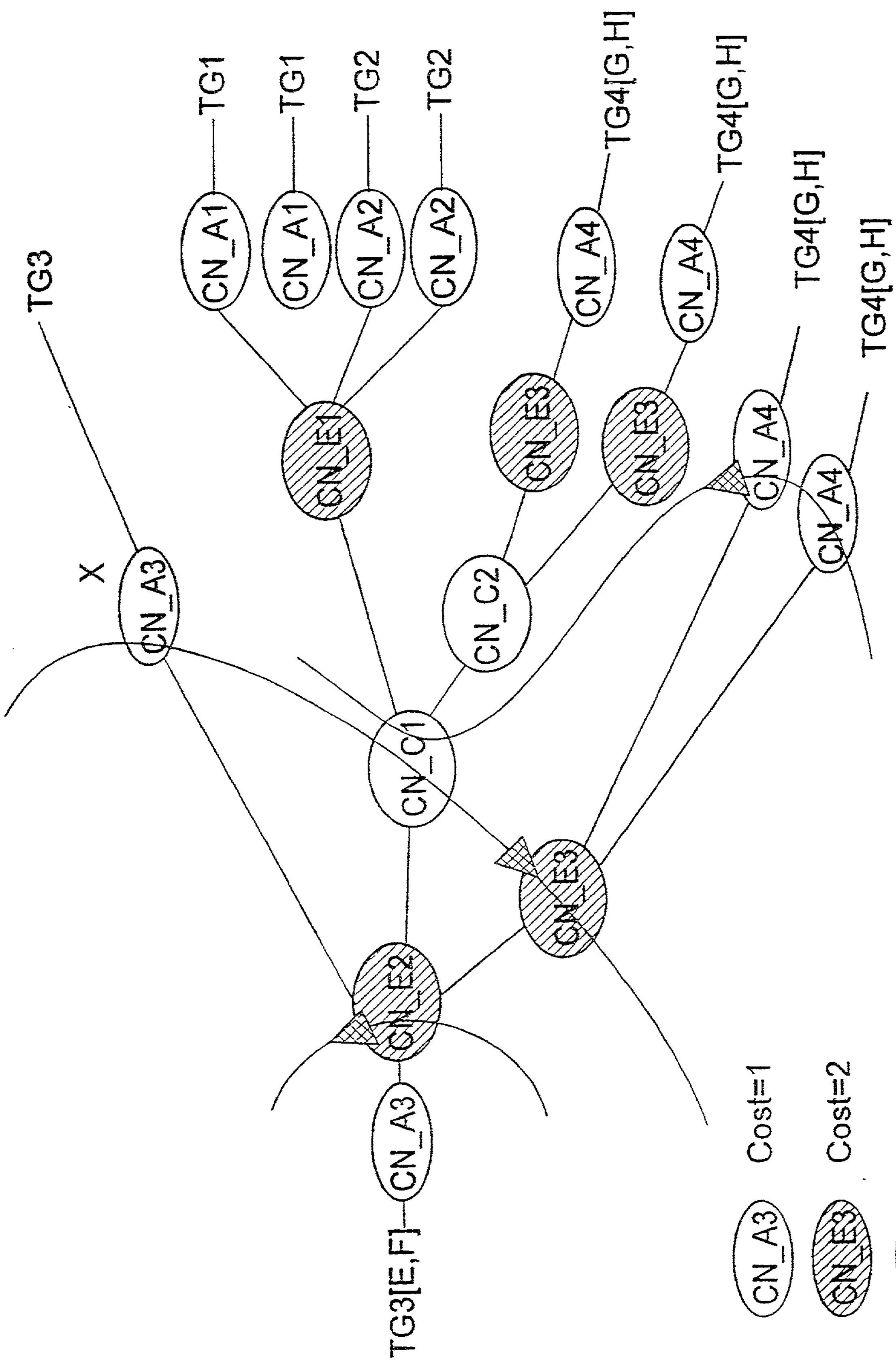

FIG. 18

COMBINED DECLARATION FOR PATENT APPLICATION AND POWER OF ATTORNEY (Includes Reference to PCT International Applications)	ATTORNEY'S DOCKET NO.

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

MANAGEMENT OF PATH SELECTION IN A COMMUNICATIONS NETWORK

the specification of which (check only one item below):

___ is attached hereto.

___ was filed as United States application
Serial No. ___________
on ___________
and was amended
on ___________ (if applicable).

X was filed as PCT international application
Number PCT/AU99/00873
on 12 October 1999
and was amended under PCT Article 19
on ___________ (if applicable).

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations §1.56(a).

I hereby claim foreign priority benefit under Title 35, United States Code, §119 of any foreign application(s) for patent or inventor's certificate or of any PCT international application(s) designating at least one country other than the United States of America listed below and have also identified below any foreign application(s) for patent or inventor's certificate or any PCT international application(s) designating at least one country other than the United States of America filed by me on the same subject matter having a filing date before that of the application(s) of which priority is claimed:

PRIOR FOREIGN/PCT APPLICATION(S) AND ANY PRIORITY CLAIMS UNDER 35 U.S.C. 119:

COUNTRY (If PCT indicate "PCT")	APPLICATION NUMBER	DATE OF FILING (day, month, year)	PRIORITY CLAIMED UNDER 35 USC 119
AUSTRALIA	PP6443	12 October 1998	X YES ___ NO
PCT	PCT/AU99/00873	12 October 1999	X YES ___ NO
			___ YES ___ NO
			___ YES ___ NO
			___ YES ___ NO

COMBINED DECLARATION FOR PATENT APPLICATION AND POWER OF ATTORNEY (CONTINUED) (Includes Reference to PCT International Applications)

ATTORNEY'S DOCKET NO.

I hereby claim the benefit under Title 35, United States Code, §120 of any United States application(s) or PCT international application(s) designating the United States of America that is/are listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in that/those prior application(s) in the manner provided by the first paragraph of Title 35, United States Code, §112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, §1.56(a) which occurred between the filing date of the prior application(s) and the national or PCT international filing date of this application.

PRIOR U.S. APPLICATIONS OR PCT INTERNATIONAL APPLICATIONS DESIGNATING THE U.S. FOR BENEFIT UNDER 35 U.S.C. 120:

U.S. APPLICATIONS		STATUS (MARK ONE)		
U.S. APPLICATION NUMBER	U.S. FILING DATE	PATENTED	PENDING	ABANDONED

PCT APPLICATIONS DESIGNATING THE U.S.					
PCT APPLICATION NO.	PCT FILING DATE	U.S. SERIAL NUMBERS ASSIGNED (if any)			

OIPE JC134 APR 11 2001 PATENT & TRADEMARK OFFICE

(13)

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith. *(List name and registration no.)* Terrance A. Meador (Reg. No. 30,298); Barry N. Young (Reg. No. 27,774); Timothy W. Lohse (Reg. No. 35,255); David Kleinsmith (Reg. No. 40,050); Gregory P. Raymer (Reg. No. 36,647); Stephen E. Reiter (Reg. No. 31,192); Darlene W. Hayes (Reg. No. 33,899); Robroy R. Fawcett (Reg. No. 35,133); James Steinberger (Reg. No. 31,798); Steven R. Sprinkle (Reg. No. 40,825); William N. Hulsey III (Reg. No. 33,402); Timothy N. Ellis (Reg. No. P41,734); Ervin Johnston (Reg. No. 20,190);

SEND CORRESPONDENCE TO: Terrance A. Meador, Reg. NO. 30,298
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San Diego, California 92101

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Terrance A. Meador
Telephone: (619) 699-2652
Fax: (619) 236-1048

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	POST OFFICE ADDRESS	POST OFFICE ADDRESS 15 Harriet Street	CITY RED HILL	STATE & ZIP CODE/COUNTRY QLD 4059 AUSTRALIA
202	FULL NAME OF INVENTOR	FAMILY NAME	FIRST GIVEN NAME	SECOND GIVEN NAME
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	POST OFFICE ADDRESS	POST OFFICE ADDRESS	CITY	STATE & ZIP CODE/COUNTRY
203	FULL NAME OF INVENTOR	FAMILY NAME	FIRST GIVEN NAME	SECOND GIVEN NAME
	RESIDENCE & CITIZENSHIP	CITY	STATE OR FOREIGN COUNTRY	COUNTRY OF CITIZENSHIP
	POST OFFICE ADDRESS	POST OFFICE ADDRESS	CITY	STATE & ZIP CODE/COUNTRY

AUX

___ ADDITIONAL INVENTOR INFORMATION ATTACHED

I hereby declare that all statements made herein are of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any issuing thereon.

SIGNATURE OF INVENTOR 201	SIGNATURE OF INVENTOR 202	SIGNATURE OF INVENTOR 203
Ian R		
DATE: 19-3-2001	DATE:	DATE: